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RESEARCH INSTITUTE, NEW DELHI.

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of the
Indiana Academy
of Science

Founded December 29, 1885

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PAUL WEATHERWAX, EDITOR

Field Meeting held at
McCormick's Creek State Park
May 13 and 14, 1938

Fifty-fourth Annual Meeting
Purdue University
November 3, 4, and 5, 1938

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INDIANAPOLIS:

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as all communications to the officers of the Academy, when their names or addresses are
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MEMBERSHIP LISTS—The complete list of members of the Academy was last published in Vol. 46 (1937) of the Proceedings, and supplementary lists appear in following volumes. For the effect that it may have in stimulating activity, a complete list of Junior Academies is published each year as a part of the report on the Junior Academy.

CONSTITUTION AND BY-LAWS—The constitution and by-laws of the Academy were last published in Vol. 44 (1935). A codified list of duties of officers and chairmen of committees is published in this volume (pp. xx-xxiv).

EDITORIAL CODE—A general editorial code was published in Vol. 44 (1935). Additional directions for the preparation of manuscripts have been printed in leaflet form, and copies of this may be secured from the Editor.

Membership lists and copies of the constitution and by-laws may be secured from the Secretary.

OFFICERS AND ELECTED COMMITTEES FOR 1938

OFFICERS

President, ELI LILLY, Eli Lilly and Company.
Vice-President, T. G. YUNCKER, DePauw University.
Secretary, WILLIAM P. ALLYN, Indiana State Teachers College.
Treasurer, W. P. MORGAN, Indiana Central College.
Editor, PAUL WEATHERWAX, Indiana University.
Press Secretary, WILL E. EDINGTON, DePauw University.
Trustees Academy Foundation, JOHN S. WRIGHT, Eli Lilly and Company,
F. B. WADE, Shortridge High School.
Committee for Bonding Trustees, H. L. BRUNER, Butler University, W. A.
COGSHALL, Indiana University.
Research Committee, A. L. FOLEY, Chairman, Indiana University (Term
expires 1941), E. G. MAHIN, University of Notre Dame (Term ex-
pires 1942), H. E. ENDERS, Purdue University (Term expires 1940),
RAY C. FRIESNER, Butler University (Term expires 1939), JOHN S.
WRIGHT, Indianapolis (Term expires 1938), ELI LILLY, Indianapolis
(ex officio), WILLIAM P. ALLYN, Indiana State Teachers College (ex
officio).

DIVISIONAL CHAIRMEN

Archeology, GLENN A. BLACK, 815 Oakland Ave., Indianapolis.
Bacteriology, P. A. TETRAULT, Purdue University.
Botany, FLOYD E. BEGHTEL, Evansville College.
Chemistry, FRANK V. GRAHAM, Ball State College.
Geology and Geography, STEPHEN S. VISHER, Indiana University.
Mathematics, J. E. DOTTERER, Manchester College.
Physics, SETH ELLIOTT, Butler University.
Psychology, A. R. EIKENBERRY, Manchester College.
Zoology, H. G. NESTER, Butler University.

EXECUTIVE COMMITTEE

(Past Presidents, Officers, Divisional Chairmen, and Chairmen
of Standing Committees)

Allen, W. P.; Andrews, F. M.; Arthur, J. C.; Beghtel, F. E.; Beh-
rens, C. A.; Black, G. A.; Blanchard, W. M.; Blatchley, W. S.; Bruner,
H. L.; Burrage, S.; Cogshall, W. A.; Coulter, Stanley; Cumings, E. R.;
Davis, J. J.; Deam, C. C.; Dotterer, J. E.; Edington, W. E.; Eiken-
berry, A. R.; Elliott, Seth; Enders, H. E.; Foley, A. L.; Friesner, R. C.;
Gingery, W. G.; Girton, R. E.; Graham, F. V.; Guernsey, E. Y.; Hessler,
R.; Lilly, Eli; Lyon, M. W., Jr.; Mahin, E. G.; Martin, E. S.; Montgom-
ery, B. E.; Morgan, W. P.; Moenkhaus, W. J.; Mottier, D. M.; Nester,
H. G.; Noyes, W. A.; Payne, F.; Ramsey, R. R.; Rettger, L. J.; Tetrault,
P. A.; Visher, S. S.; Wade, F. B.; Wallace, F. N.; Weatherwax, Paul;
Wright, J. S.; Yuncker, T. G.

STANDING COMMITTEES

(Appointed by the President, chairman of each committee named first.)

Archeological Survey: E. Y. Guernsey, Eli Lilly, W. N. Logan, Glenn A. Black, C. A. Malott, R. E. Esarey, C. F. Voegelin.

Auditing: E. S. Martin, William Johnson.

Biological Survey: B. E. Montgomery, Winona Welch, C. M. Palmer, S. R. Esten, M. W. Lyon, B. H. Smith.

Library: Walter G. Gingery, Ray C. Friesner, Nellie M. Coats.

Membership: R. E. Girton, S. W. Witmer, Floyd E. Beghtel, M. S. Markle, L. J. Rettger, Glenn W. Giddings, G. D. Klopp, O. B. Christy, W. D. Thornbury, R. E. Martin, Francis J. Wenninger, A. R. Bechtel, C. A. Deppe, Howard H. Helman, F. R. Elliott, William J. Tinkle, Henry G. Nester, Leslie I. Steinbach, D. L. Harmon, H. M. Powell.

Program: J. J. Davis, R. B. Abbott, R. H. George, H. H. Remmers, C. A. Malott, Glenn A. Black, Ray C. Friesner, C. K. Robbins, Theodore Just, R. E. Martin.

Publications of Proceedings: Paul Weatherwax, J. J. Davis, C. A. Behrens, F. B. Wade, M. E. Hufford, E. S. Conklin.

Relation of Academy to State: F. N. Wallace, J. S. Wright, Stanley Coulter, E. Y. Guernsey, Harry J. Reed, D. A. Rothrock.

Representative on A.A.A.S. Council: Howard E. Enders.

Nominations: Will E. Edington, J. J. Davis, Ray C. Friesner.

Junior Academy of Science: Howard E. Enders, F. B. Wade, O. B. Christy, W. P. Allyn, Fred J. Breeze, C. F. Cox.

MINUTES OF COUNCIL MEETING

INDIANAPOLIS, MARCH 5, 1938

The Executive Council meeting at the Indianapolis Athletic Club, held primarily to consider problems pertinent to the spring meeting and other current business needing attention before the regular meeting, was called to order by President Lilly at 1:30, following a luncheon. Twenty-five members of the committee were present: W. P. Allyn, F. E. Beghtel, C. A. Behrens, G. A. Black, W. M. Blanchard, H. L. Bruner, W. A. Cogshall, Stanley Coulter, J. J. Davis, J. E. Dotterer, W. E. Edington, A. R. Eikenberry, Seth Elliott, W. G. Gingery, R. E. Girtton, F. V. Graham, Eli Lilly, E. S. Martin, W. P. Morgan, D. M. Mottier, H. G. Nester, P. A. Tetrault, S. S. Visser, Paul Weatherwax, T. G. Yuncker.

The minutes of the previous business meeting, at Manchester College, November 4, 1937, were read and approved with two minor corrections. The reference made to the Treasurer's report was corrected to read that the Treasurer submitted a brief report, and the name of W. P. Allyn was added to the list of fellows elected.

Officers and committees reported as follows:

Auditing Committee. E. S. Martin stated that the Treasurer's books at the last audit were in excellent condition. No audit has been made for the current year, since the fiscal year ends December 31.

Treasurer's Report. W. P. Morgan briefly indicated the financial status of the Academy to date with a balance of \$810.01.

A discussion followed as to the advisability of transferring some of the balance to the research fund, but action was postponed until the regular fall meeting.

Editor. Dr. Weatherwax spoke briefly on the status of the Proceedings for 1938, stating that it was ready to go to press, also that an attempt was being made to publish abstracts of all papers not published in full. He asked the Council to appropriate \$300 to supplement the \$1,000 contributed by the state for publishing and binding the Proceedings.

The appropriation was approved.

A bill for \$1,000 due the publishers of the 1937 Proceedings was brought up for discussion. Due to a minor discrepancy, the lack of the official o. k. of the Editor, this bill had not been paid. It was voted that the matter be placed entirely in the hands of Mr. F. N. Wallace, Chairman of the Committee on the Relations of the Academy to the State, for the execution of necessary proceedings for payment of the bill.

Program Committee. J. J. Davis reported that the Committee had decided on McCormick's Creek State Park as the place for the spring meeting and that two tentative dates from which to choose were sug-

gested, May 18 to 14 and May 20 to 21. It was voted that McCormick's Creek State Park be selected as the place and that May 18 and 14 be approved as the date.

New Business. Acting upon the previous suggestion of Professor Kintner, President Lilly appointed a committee of three, Dr. Edington, Dr. Friesner, and J. S. Wright, as an advisory committee on duties of Academy officers and committee chairmen. The function of this committee is to formulate suggestions and helps for the committee chairmen, divisional chairmen, and other officers in the performance and integration of the duties of their respective offices.

President Lilly expressed his appreciation for the attendance of the members of the Council, especially during such inclement weather, and begged that they be his guests at the luncheon. A vote of hearty appreciation of his hospitality followed, and the meeting was adjourned.

MINUTES OF THE SPRING MEETING

MCCORMICK'S CREEK STATE PARK

MAY 13 AND 14, 1938

The members of the Academy assembled in the Lounge Room of Canyon Inn at McCormick's Creek State Park for the annual spring meeting. The meeting was called to order by President Eli Lilly, who welcomed those in attendance and thanked the members of the Program Committee and other officers concerned for their splendid cooperation in preparing for the meeting.

An informal program followed. Dr. Clyde A. Malott shared with the Academy his store of knowledge on "The Setting and Geological Features of McCormick's Creek Park Area." Dr. A. C. Kinsey's discussion on the "Pleistocene Glaciation Effects on Indiana Fauna and Flora" challenged certain scientific concepts concerning species variation in this area. Dr. Paul Weatherwax discussed "Plants Rare and Common in McCormick's Creek Park Area." Dr. Marcus Ward Lyon, Jr., submitted a tribute to the memory of the splendid work of the late Dr. Bebb.

President Lilly appointed the following Nominating Committee for 1938: Will Edington (chairman), J. J. Davis, and Ray C. Friesner.

The evening meeting was then adjourned.

Several trips were planned for Saturday morning, May 14, but rain interfered with the greater part of the program.

(Signed) WILLIAM P. ALLYN, *Secretary*.

PROGRAM OF THE WINTER MEETING

PURDUE UNIVERSITY
NOVEMBER 3-5, 1938

THURSDAY, NOVEMBER 3

- 7:00-9:00 p. m. Registration.
7:30 p. m. Meeting of the Executive Committee.

FRIDAY, NOVEMBER 4

- 8:00-12:00 a. m. Registration.
9:30 a. m. General Session.
Address of Welcome—Professor F. C. Hockema, Assistant to the President of Purdue University.
Response—President Eli Lilly.
Business Session.
Necrology—Dean Stanley Coulter.
Sister Amata
Charles Brossman
William Bebb
Kate G. Bitting
Fred Donaghy
Joseph P. Naylor
"The life and work of Joseph Charles Arthur."—Frank D. Kern, Pennsylvania State College.
"A tribute to Dean Stanley Coulter."—Ray C. Friesner, Butler University.
"Indiana Mastodons."—Marcus W. Lyon, Jr., South Bend.
"Marihuana."—B. H. Smith, Indiana State Teachers College.
"The distribution of corn, oats, and wheat in Indiana."—S. S. Visher, Indiana University.
1:00 p. m. Sectional meetings. See: archeology, p. 12; bacteriology, p. 33; botany, p. 44; chemistry, p. 74; geology and geography, p. 113; mathematics, p. 157; physics, p. 171; psychology, p. 183; zoology, p. 200.
6:00 p. m. Annual Dinner.
Business Session.
8:00 p. m. "Bubbles Concerto—A film fantasy."—Eiffel G. Plasterer and party, Huntington.
President's Address—"A plan for accomplishing more effective research."—Eli Lilly, Indianapolis.

SATURDAY, NOVEMBER 5

- 9:00 a. m. Meeting of entomologists—Chairman, Philip Luginbill, U. S. Department of Agriculture. See p. xxviii.
Meeting of plant taxonomists—Chairman, Ralph M. Kriebel, Soil Conservation Service. See p. xxviii.
Junior Academy of Science. See p. xxv.
1:00 p. m. Junior Academy of Science.

MINUTES OF THE EXECUTIVE COMMITTEE

NOVEMBER 3, 1938

The meeting was called to order at 7:30 by President Lilly. The minutes of the Executive Council at Indianapolis, March 5, 1938, and also those of the spring meeting, held at McCormick's Creek State Park, were read by the Secretary and approved.

Officers and committees gave the following reports:

Academy Foundation. John S. Wright, in the absence of Chairman Frank B. Wade, gave the following report as of November 1, 1938:

Receipts	
Balance from previous year.....	\$ 352.01
Total receipts	760.57
Total	\$1,112.58
Expenditures	
No expenditures	000.00
Balance in Indiana National Bank.....	\$1,112.58
Present Assets at Par Value	
United States Treasury Bonds.....	\$4,700.00
Consolidated Federal Farm Loan Bonds.....	1,500.00
Muncie Masonic Temple Association Preferred Stock.....	200.00
Standard Oil Co. of Indiana Common Stock.....	150.00
Total invested assets at par.....	\$6,550.00
Balance in bank (awaiting investment).....	1,112.58
Grand total assets.....	\$7,662.58

Archeological Survey. Mr. Guernsey gave an informal report of the activities of the committee for 1938, this being a continuation of work of the previous year with emphasis on studies in southern areas of Indiana.

Auditing Committee. Mr. Martin stated that, since the Academy year closed December 31, no audit was yet available for 1938. The Auditing Committee, however, had examined the books of the Treasurer and found that his report appearing in Volume 47 of the Proceedings was a true statement of receipts, expenditures, and balance on hand for the Academy.

Also the books of the Trustees of the Academy Foundation Fund were found to be correct and to agree with the report given by the trustees in Volume 47 of the Proceedings.

Biological Survey. B. E. Montgomery submitted the following report:

The committee is pleased to be able to report that Deam's Flora of Indiana has been completed and is in the hands of the printer. Other items of interest, including the bibliography of Indiana biota, are little changed from last year.

The committee wishes again to call attention of the Academy to the urgent need for a research museum within the state. It is hoped that the special committee authorized last year on the recommendation of our committee will be able to report progress on the preliminary steps for such museum.

Bonding Committee. *Dr. H. L. Bruner, who was unable to be present, submitted a written report to the effect that the premium of \$15.00 on the bond for the Treasurer and Trustees of the Academy was due.*

Payment of the bill was authorized.

Editor. Dr. Weatherwax, Editor, reported that Volume 47 was delivered to the State Library in August. The details pertaining to the publication of the volume are as follows:

Number of copies printed	1800
Number of pages printed	324
Cost of printing and binding.....	\$1,432.22
Cost of reprints furnished gratis to authors.....	58.53
Cost of reprints of necrology and membership list.....	17.70
Editorial assistant	180.20
Editor's expenses for postage, envelopes, etc.....	10.00
Total cost of publication.....	1,698.65
Amount paid by the Academy.....	898.65
Total cost per printed page.....	5.24
Net cost per page of manufacture.....	4.41

The net cost per printed page has increased about 10% in the past two years. A part of this is attributed to the new scale of contract prices and a part to the condensation of material on the pages. Random samples indicate that the cost per unit of printed matter has shown no material increase.

Dr. Weatherwax also stated that, so far as possible, abstracts of all papers were published.

It was also asked by Dr. Weatherwax that a stipulated sum to be used in publishing the Proceedings be named by the executive committee. The Treasurer suggested that the financial standing of the Academy would permit an expenditure equal to that of last year for publishing the Proceedings.

An amended motion, to the effect that the amount to be spent on the publication of the Proceedings for 1938 be left to the discretion of the Editor and the Treasurer, provided that it did not exceed \$600, was passed.

The expenditure of an amount not to exceed \$200 for editorial assistance was authorized.

Library Committee. W. G. Gingery read the following report prepared by Miss Nellie Coats of the State Library:

Since the last annual report 25 new titles, a list of which is appended, have been added to the number of serials received by the Library, making a total of about 300, representing material from 89 states, the Philippines and Hawaii, and 27 foreign countries. An effort is made not only to acquire material representing various scientific fields but to extend the geographic range as widely as possible. We hope to acquire material from such states as are not represented, if material is available, and to expand the foreign mailing list. The foreign countries now represented are: Argentina, Australia, Austria, Belgium, Borneo, Brazil, Canada, Chile, China, Czechoslovakia, Denmark, Dutch East Indies, England, Finland, France, Germany, Greece, Hungary, India, Ireland (Northern), Italy, Japan, Latvia, Mexico, The Netherlands, Norway, Peru, Poland, Portugal, Roumania, Russia, Scotland, South Africa, Sweden, Switzerland, Ukraine, and Uruguay.

Recently the new edition of the National Research Council Handbook of Scientific and Technical Societies and Institutions of the United States and Canada and the 1937 Index Generalis were checked for names and addresses of additional scientific societies and institutions with which it might be profitable to establish the exchange of publications, and letters have been sent to 52 societies and universities asking that such an arrangement be made.

In May, 1938, a letter was received from the National Library of Peiping, China, which we quote:

"Owing to Japan's military occupation of Peiping, we have established an office in Hongkong. We have been collecting books and journals in order to meet the intellectual needs of Chinese scholars in this hour of distress. As many of our universities and scientific institutions have been deliberately destroyed by Japanese militarists, the need of scientific literature felt by Chinese scholars is most urgent.

"Cognizant of your intellectual sympathy for China, we earnestly hope that you will find it possible to send us a set of the following publications issued by your Academy: Transactions, other publications which you distribute to cultural institutions.

"If you would kindly comply with our request, your courtesy will be gratefully appreciated.

"As we have to start our work entirely afresh, we shall greatly appreciate your assistance if you could send us also your duplicate material which you no longer wish to keep.

"Donations of books from your Academy will temporarily be kept in Hongkong and will be properly catalogued and made immediately available for use. As scientific work is being carried on in China despite of the war, your publications will render a great service to the present and future generations of scientific workers in this country.

"In order to save you the trouble of posting your publications to China, we may suggest that you forward them to the International Exchange Service, Smithsonian Institution, Washington, D. C., which would arrange their shipment to us at our Hongkong address. The current issues of your serial publications, however, should be sent by mail so that Chinese scholars will be able to keep in touch with your scientific work.

"Thanking you in anticipation for your cooperation and assistance, I remain

"Very truly yours,

"(Signed) T. L. YUAN, Acting Director."

The following year books were sent in response to this request: 1887, 1889, 91, 93-1913, 1915, 1919, 1924, 1927, 1930, 1931, 1935-37.

The work of checking titles for entry in the Union list of serials in Indiana libraries, sponsored by the College Reference Librarians of Indiana, is nearing completion, and the list should be ready for publication within the year. It is thought that inclusion in this list will greatly add to the library's usefulness.

With the Academy's appropriation of a sum for binding for the years 1937-38 and 1938-39 it is hoped that most of the complete files will be bound during this two-year period. Late in 1937, 445 volumes of serials, chiefly publications of foreign scientific organizations, were bound, and it is estimated that about as many volumes are now ready for binding. These will be prepared and sent to the bindery in the very near future. There will remain the task of filling in incomplete files and binding material received each year. Every effort has been made to secure missing numbers by gift or exchange from the issuing societies or institutions, and it is fairly evident that volumes now remaining incomplete can only be completed by the purchase of the missing numbers if that is considered advisable.

Titles Added to the Library Since 1937

- Association canadienne française pour l'avancement des sciences *Annales*. 1, 1935.
- Archives néerlandaises de phonétique expérimentale v. 4, 1929.
- Athens. University. Zoological institute and museum *Acta* v. 1, 1935.
- Australian zoologist v. 1, 1914.
- La bonne terre. Ecole supérieure d'agriculture v. 19, December, 1937.
- Chicago naturalist. Chicago academy of science v. 1, 1938.
- Condor v. 40, 1938.
- Fysiografiska sällskapet. Lund, Sweden. *Forhandlingar* v. 6, 1938.
- Harvard university. Museum of comparative zoology *Bulletin* v. 78, 1935.
- Hawaii. University Research publications no. 8, 1938.
- Instituto pan-americano de geografia e antropologia a americano *Boletim bibliografico de antropologia americano* v. 1, 1937.
- London. Science museum. Science Library. *Weekly bibliography* May, 1937.
- Missouri academy of science *Proceedings* 1934-35.
- New Orleans academy of science *Abstracts of papers* 1938.
- Northwest science. Northwest scientific association v. 1, 1927.
- Rivista de biologia coloniale. Rome v. 1, 1938.

Royal Ontario museum of zoology Contributions 1, 1935.
 Royal zoological society of New South Wales Proceedings 1935-36.
 Saratov. Universität Abhandlungen: Chemische serie 1, 1936.
 Saratov. Universität Geologisch-bodenwissenschaftlichen serie 1, 1937.
 Scripps institution of oceanography Contributions n. s. 1, 1937.
 Shanghai science institute Journal 1938.
 Societas pro fauna et flora Acta v. 58, 1935-36.
 Societe entomologique de Belgique Bulletin et annales v. 75, 1935.
 Yale university. School of forestry Bulletin no. 43, 1936.

Membership Committee. R. E. Girton, Chairman, stated that 55 applications for membership in the Academy were obtained for the fall meeting. To this list should be added seven other names of those elected at the spring meeting.

It was suggested that all members of the Academy should be on the alert for prospective new members in order that the membership may show a positive growth during the years to come.

Press Secretary. Dr. Edington gave the following summary of the activities of his office:

Reports of the Spring Meeting of the Academy were sent to the Indianapolis papers and to the Editor of *Science*. Reports of the present meeting have appeared in the Indianapolis papers and in papers elsewhere. The Indianapolis News carried an editorial in its issue of November 2, commenting favorably on the work of the Academy and the scientists of the State. Since clipping service is not available, the Press Secretary has no means of ascertaining how extensive over the State the Academy publicity may be. Abstracts of most of the papers to be presented before the Academy have been received, and it is planned that stories on some of them will be released on the day of the presentation of the papers.

Relations of the Academy to the State. Frank N. Wallace stated that his committee had made a request for \$1,500 from the state, the same amount as that granted last year, for the publication and binding of the Proceedings—\$1,000 for publication of Proceedings and \$500 for binding Proceedings and other manuscripts and records belonging to the Academy.

Research Committee. Dr. Foley gave a brief report of grants made for 1938 but stated that no application for future grants had been received by the committee.

The committee awarded \$75 to S. S. Visser, Indiana University, for clerical help in the analysis of climatological data and for traveling expenses to meteorological stations of the state.

A grant of \$125 was awarded to Dr. W. M. Blanchard, DePauw University, to continue studies of new methods for synthesizing derivatives of mandelic acid, investigations on the composition of certain vegetable oils, and preparation of ozetidine derivatives.

It was proposed by the committee when the grants were made that \$150 of the total sum be furnished by the research grant from the A.A.A.S. to the Academy, and the remaining \$50 be paid from the funds of the Academy. It was reported that \$150 had been received from the A.A.A.S. and that both grants, as indicated, had been paid in full to the grantees.

The Chairman stated that reports on the progress of the research work had been received from Dr. Visser, but that, on account of illness, no report had been received from Dr. Blanchard.

MINUTES AND RECORDS

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Treasurer. Dr. W. P. Morgan submitted a tentative report to cover the period from January 1 to October 31, 1938. The following report for the fiscal year, ending December 31, 1938, was later submitted:

Receipts	
Balance on hand January 1, 1938.....	\$810.01
Dues and Initiation fees.....	856.00
A. A. A. S. refund for research grants.....	150.00
Sale of Proceedings.....	21.32
Sale of separate numbers of journals.....	4.25
Return of unused research grant (Martin).....	1.40
Authors' reprints, Volume 46.....	4.89
Authors' reprints, Volume 47.....	298.67
Bequest from estate of Dr. Stoltz.....	40.00
	\$2,181.44
Disbursements	
Program Committee.....	\$126.00
Expenses of Editor.....	207.50
Expenses of Secretary.....	80.78
Expenses of Treasurer.....	47.00
Mailing Proceedings.....	95.52
Stationery.....	55.35
Indianapolis Engraving Co.....	183.25
Wm. B. Burford Printing Co.....	788.63
Junior Academy, Science club bulletins.....	20.00
Surety bond and safety deposit box.....	20.50
Expenses local committee, A. A. A. S. meeting.....	31.81
Payment of Stoltz bequest to Foundation.....	40.00
Research grants (Wilson, \$75; Blanchard, \$125; Visher, \$75.00).....	275.00
Returned check.....	4.92
Bank service charge.....	.50
Expense refund to officers and chairmen.....	12.15
	\$1,983.01
Bank balance.....	198.43
	\$2,181.44

The balance indicated above as carried forward from 1937 is \$1.00 more than that published in the preceding annual report, due to a loss of a check for \$1.00 by an officer. This is covered by a duplicate listed under the last in the above list of disbursements.

(Signed) W. P. Morgan, *Treasurer.*
 Ersie S. Martin, *Auditor.*
 Wm. Johnson, *Auditor.*

Junior Academy Committee. Dr. Enders reported that to date there are about forty active junior organizations and several prospective clubs under consideration. A mailing list and visitation itinerary have been established in order to familiarize the high schools of the state and capture their interest with this phase of the Academy's program.

It was emphasized that exhibits of the Junior Academies would be on display Saturday morning and that it would be not only interesting to visiting members of the Academy but also stimulating to the Junior Academy representatives if they were honored by the attendance of members of the senior Academy.

At the suggestion of Dr. Enders, it was voted to appropriate \$20 again this year for the cooperative publication, with the Illinois Academy, of the Science Club Service to be distributed among the Junior Academies and prospective clubs.

Nominating Committee. Dr. Joseph Charles Arthur was nominated as Honorary Fellow, and the following were nominated as Fellows: F. E. Beghtel, Ralph Kriebel, W. D. Thornbury, F. V. Graham, and B. H. Smith. H. L. Bruner and W. A. Cogshall were nominated to succeed themselves on the Bonding Committee, and John S. Wright to succeed himself on the Research Committee, his term to expire in 1943.

All the above nominees were elected. The nominations of other officers of the Academy were withheld until the dinner meeting.

Necrology. Dean Coulter, who has for many years collected data for the necrology, requested that this duty be assigned to a younger man with close acquaintance with the membership and affairs of the Academy. It was voted that this duty be assigned to Dr. Will E. Edington until a change was officially designated.

Relation of High School Teachers to the Academy. Means of encouraging high school teachers to attend the Academy were discussed. Dr. Edington stated that the permission for teachers to be absent from duty in order to attend the Academy meetings lay entirely in the hands of local school officials and that, through local science clubs, school officials might be encouraged to recognize the value of these meetings and to cooperate.

It was voted that a committee be appointed to acquaint school officials with the program of the Academy and to enlist their cooperation in the participation of teachers in Academy programs.

Program Improvement. It was decided in 1937, at the suggestion of a special committee under Dr. Friesner, that papers of special merit read before the Academy be selected by the Research Committee and given honorable mention at the dinner meeting following the sectional meetings.

Dr. Foley, Chairman of the Research Committee, asked that this be omitted this year and indefinitely until satisfactory machinery could be organized for handling this problem. He stated that the magnitude of the job and brevity of time during the course of meetings presented a physical impossibility. Dr. Foley's request was granted. It was suggested that honorable mention of worthy papers might be made at the first succeeding annual meeting.

Correlation of Duties of Officers. Dr. Edington, as Chairman, reported that the special committee on duties of officers, which had been authorized by the Council at its meeting in March, had practically completed its work. He gave a brief resume of what had been accomplished and asked that the completed report be mimeographed for immediate use and also published in the Proceedings and that reprints be prepared for distribution to officers in the future. The report was approved, and its publication was authorized. (The codified list of duties of officers is published in full on pages xx to xxiv.)

President Lilly appointed the following committees: *Invitations*—L. A. Test, Glenn A. Black, and O. B. Christy; *Resolutions*—C. A. Malott, Paul Weatherwax, and B. E. Montgomery.

The meeting adjourned at 10:30 p. m.

MINUTES OF THE GENERAL SESSION

The meeting, with 433 registrations, was called to order at 9:30 a. m. in Eliza Fowler Hall by President Lilly. An address of welcome was given by Professor F. C. Hockema, Assistant to the President of

Purdue University. President Lilly responded briefly to the welcome and expressed the appreciation of the Academy for the hospitality extended by the University.

In the brief business session which followed, the action of the Executive Committee was approved. J. J. Davis, Chairman of the Program Committee, commented briefly on minor changes which had been made since the printing of the program.

Dean Coulter paid appropriate tribute to the memory of six members of the Academy whose deaths had occurred during the past year: Sister Amata, Kate G. Bitting, Charles Brossman, William Bebb, Fred Donaghy, and Joseph P. Naylor.

The meeting adjourned at 11 o'clock, a. m., and the sectional meetings convened at one o'clock.

The annual Academy dinner was held in the Purdue Union Building at 6 p. m. A short business meeting followed the dinner. Dr. Girton, Chairman of the Membership Committee, submitted the names of 54 applicants for membership, and all were elected.

The Resolutions Committee offered the following resolution:

The Indiana Academy of Science, assembled at Purdue University in its fifty-fourth annual meeting, expresses its sincere appreciation for the hospitality offered by the University, for the careful preparations made by its Program Committee under the leadership of Professor J. J. Davis, for the efficiency and interest demonstrated by its officers, and for the presence of a large number of its membership, who demonstrate their interest in the progress of science in Indiana by their presence and participation in the programs.

The Committee on Invitations recommended that the Academy accept the invitation of the Indiana State Teachers College to be the host for the Academy at its next annual winter meeting, 1939. The recommendation was approved.

The Nominating Committee announced the election of the Division Chairmen as follows: *Archeology*, Paul Weer, Indianapolis; *Bacteriology*, W. A. Jamieson, Eli Lilly and Company; *Botany*, Winona Welch, DePauw University; *Chemistry*, Herman T. Briscoe, Indiana University; *Geology and Geography*, Thomas M. Bushnell, Purdue University; *Mathematics*, P. D. Edwards, Ball State Teachers College; *Physics*, R. B. Abbott, Purdue University; *Psychology*, F. B. Knight, Purdue University; *Zoology*, C. P. Hickman, DePauw University.

The following were nominated for officers for 1939: *President*, T. G. Yuncker, DePauw University; *Vice-President*, L. A. Test, Purdue University; *Secretary*, W. P. Allyn, Indiana State Teachers College; *Treasurer*, W. P. Morgan, Indiana Central College; *Editor*, Paul Weatherwax, Indiana University; *Press Secretary*, W. E. Edington, DePauw University. It was voted that the Secretary be instructed to cast a unanimous vote for the election of these nominees.

The meeting was then placed in charge of the new President, and Retiring President Lilly delivered a very interesting and thought-provoking address on "A Plan for Accomplishing More Effective Research."

Entertainment followed and the meeting was adjourned.

(Signed) W. P. ALLYN, *Secretary*.

DUTIES OF OFFICERS

The following list of duties of officers and committee chairmen of the Academy was prepared by a special committee, consisting of Will E. Edington (Chairman), John S. Wright, and Ray C. Friesner, and approved by the Executive Committee at the Winter Meeting of 1938.

President

1. To preside at all meetings of the Academy except when relieved by the Vice-President.
2. To appoint the members of the standing committees and any special committees. To appoint the members of the Nominating Committee, Invitations Committee, and Resolutions Committee. It is suggested that the Nominating Committee be chosen from past presidents.
3. To approve the current bills of the Academy.
4. To deliver an address, known as the Presidential Address, at a time specified by the Program Committee.
5. To cooperate closely with the Committee on Relation of the Academy to State in the securing of funds for the publication of the Proceedings, library improvements, and similar projects.
6. To call special meetings of the Council or Executive Committee as occasion demands. A special Council Meeting is generally held in late February or early March in order to make general plans for the year.
7. To perform other such duties as pertain to the office.

Vice-President

1. To preside in the absence of the President and otherwise at the request of the President.
2. To preside and introduce the President at that session or that part of the session at which the President makes his Presidential Address.
3. To perform other such duties as usually pertain to the office.

Secretary

1. To keep the minutes of the meetings of the Council, the Executive Committee, and of all General Sessions of the Academy, and to prepare these minutes for publication in the Proceedings. The form in which these minutes should appear may be found in past volumes of the Proceedings. The minutes of the Executive Committee just preceding the General Winter Meeting should be prepared for reading at the General Meeting the following morning. Also the nominations for fellows of the Academy should be presented at this General Meeting.
2. To furnish the President or other officers complete copies of the minutes or such parts as they may specifically request.
3. To notify promptly the President and Committee Chairmen of any items in the minutes which they should know or which require their action.
4. To keep a complete file of the membership of the Academy as furnished by the Treasurer, and to have charge of the mailing lists of all Academy notices and the Proceedings, and to supply such lists upon request to the Chairman of the Program Committee and the proper officials of the State Library.
5. To notify the Chairman of the Program Committee that, upon his request, addressed envelopes will be supplied him for mailing:
 - a. Preliminary Spring Meeting notices, these to be window envelopes and to include addressed dues notices, the amounts to be filled in by the Treasurer.
 - b. Final Spring Meeting notices.
 - c. Preliminary Winter Meeting notices.
 - d. Final winter program.

6. To address dues notices for Treasurer upon his request. When a new treasurer is elected, to inform him of this service.
7. To address envelopes for Chairman of the Program Committee. Three sets are needed: one for final Spring Meeting announcement, one for preliminary Winter Meeting announcement, and one for final Winter Meeting announcement. Preliminary Spring Meeting announcements go out in window envelopes containing also the dues notices. Final notices of meetings are sent to non-resident members.
8. To address labels for mailing out Proceedings to active members. Check slips against "dues paid" for years for which Proceedings are current. Those who have not paid dues receive no Proceedings. Non-resident members who pay no dues do not receive the Proceedings.
9. To prepare membership roll after the Winter Meeting. Make at least two copies and send one copy to the Editor and keep one copy in reserve.
10. To keep on file statements as to the duties and modes of procedure of the Chairman of the Program Committee, the Chairman of the Research Committee, and the chairmen of the divisions, and to inform these various chairmen of their respective duties in sufficient time preceding the meetings. See duties of these officers.
11. To secure Academy stationery. For amounts and those to whom it goes see yearly card records filed with minute book.
12. To notify all new members of their election. Use form cards.
13. To send notices to all members elected as Fellows or Honorary Fellows or otherwise honored. Send notices to all newly elected officers who were not present when election was held.
14. To send copies of all resolutions to persons concerned.
15. To send the new President a list of all old committees with suggestions regarding new committees.
16. To send out lists of committees to all members of committees as soon as they are appointed by the new President. Include a note informing chairmen that reports will be expected at the Winter Meeting.
17. To notify all members of Executive Committee of all meetings of this committee. The Executive Committee consists of present officers, past presidents, chairmen of standing committees, and divisional chairmen. Notify them one month before Winter Meeting and remind them of written reports due at the Winter Meeting.
18. At the request of the President, to notify all members of the Council concerning meetings of the Council. The Council is composed of the officers of the Academy.
19. To inform the Chairman of the Nominating Committee one month preceding the Winter Meeting that the nominations of Fellows and Honorary Fellows must be presented at the Executive Committee Meeting.
20. To correct membership file whenever changes of address occur. Change must also be made on addressograph stencil. Destroy old stencil, and type card for the new one. Send cards to Elliott Addressograph Company, Indianapolis, for stencils twice annually, about January 1 and August 1. Inform Treasurer of all changes of address as they come.
21. All current bills of the Academy must be approved by the Secretary and the President before they are paid by the Treasurer. Approval of bills should be given promptly so that, whenever possible, discounts for cash may be secured.
22. Preceding meetings of the Executive Committee, to prepare for the President an order of business and bring to his attention any matters of incomplete business as found in the minutes of the preceding meeting.
23. At all meetings of the Council, Executive Committee, and general Academy, to have available the minute book containing the constitution and by-laws, list of committees and editor's code, and also a copy of the last Proceedings.
24. To perform other such duties as usually pertain to the office.

Treasurer

1. To handle all funds of the Academy currently received and not otherwise provided for.
2. To keep the financial records of the Academy, and to pay all bills of the Academy that have been previously approved by the President and the Secretary.
3. To notify the members annually of their standing as to membership dues, and to render statements to members for charges for reprints, etc. At the request of the Treasurer, the Secretary will send to the Treasurer the addressed dues notices, upon which the Treasurer will fill in the proper amounts before sending the notices to the Chairman of

the Program Committee so that the dues notices may be sent out with the preliminary Spring Meeting notices.

4. To inform the Secretary concerning the addition of new members and the dropping of old members for non-payment of dues, so that the membership lists may be kept correct and up to date. The Treasurer should turn over promptly all "dues paid" cards to the Secretary.

5. To receive all refunds from the A. A. A. S., such refunds to be used only for research grants as recommended by the Research Committee and authorized by the Academy.

6. To receive such funds from the Academy Foundation as have been allotted for research grants, and to pay such funds to research grantees as have been recommended by the Research Committee and authorized by the Academy. See Proceedings for 1938, Volume 47, page 10.

7. To prepare tentative and permanent statements showing clearly the financial status of the Academy, and to prepare and have audited a financial statement at the end of the fiscal year for publication in the Proceedings. A tentative statement should be presented at the Winter Meeting of the Executive Committee, and the Treasurer should anticipate receipts and be prepared to advise the officers in matters involving appropriations.

8. To provide the Editor with information concerning the status of members submitting papers for publication.

9. To perform other such duties as may pertain to the office.

Editor

1. To edit all manuscripts of papers presented on the programs of the Academy which are submitted and accepted for publication in the Proceedings. See statement of editorial policy and editorial code in the Proceedings, Volume 44, page 257.

2. To make such contracts and arrangements as are necessary for the publication of the Proceedings and as are consistent with the accepted policy of the Academy in its cooperation with the state in such publication.

3. To approve all bills arising from the publication of the Proceedings and to send these bills to the President and Secretary for their approval before payment by the Treasurer.

4. To file with the Treasurer statements of all charges for reprints and any other charges incurred by members in the publication of the Proceedings.

5. To publish in each volume of the Proceedings a statement referring to the report on the duties of officers and giving the number of the volume in which it is published.

Press Secretary

1. To have general charge of the publicity of the Academy and to prepare for the use of college directors of publicity, reporters, and editors such material as will inform the citizens of the state as to the nature of the activities and the purposes of the Academy.

2. To gather photographs, programs, and other material of general and historical interest for the files of the Academy in the State Historical Library.

3. To prepare statements concerning the meetings of the Academy suitable for publication in *Science*.

4. To cooperate with publicity directors of the institution where the Academy may be holding its meetings in the preparation of any publicity which the institution may deem desirable concerning the Academy and its activities. Photographs of officers and outstanding speakers should be secured whenever possible at least one month preceding the Winter Meeting and of new officers immediately following their election.

5. The photograph of each new president and any other outstanding member should be secured and placed in the Academy files in the State Historical Library.

Chairman of the Program Committee

1. In cooperation with his committee, to choose the place and prepare the program for the Spring Meeting of the Academy.

2. To prepare the general program for the Winter Meeting, and to appoint a local committee on arrangements to assist in the work of preparing for the meeting.

3. To compile the special programs as received from the divisional chairman, and to prepare and have published complete programs of all meetings of the Academy, together with such additional information as may be deemed necessary for the convenience of the members, such as hotel accommodations, road information, transportation facilities, etc.
4. To send to each member of the Academy the programs of the various meetings. The addressed envelopes are to be prepared by the Secretary and forwarded to the Chairman of the Program Committee at the Chairman's request.
5. To have general charge of all arrangements for the meetings of the Academy, such as luncheons, banquets, hotel arrangements, transportation, the providing of lanterns and screens, suitable locations for Junior Academy exhibits, etc.
6. To cooperate with the Academy Committee on the Junior Academy of Science in the making of the plans and arrangements for the meetings of the Junior Academy. The program of the Junior Academy Meeting is published as a part of the program of the Winter Meeting of the Academy.
7. To arrange, if possible, an information system whereby during the division meetings the members of the various divisions may be kept informed as to what papers are being read in the various divisions.
8. To receive the abstracts in triplicate of papers presented on the general program and promptly to send one abstract to the Editor, one to the Press Secretary, and one to the Chairman of the Research Committee.
9. To secure for announcement in the Winter Meeting program, a list of the names of all Academy members who have become deceased during the year, and to cooperate with the Academy necrologist in the preparation of memorials. Write to the Secretary for information.
10. To provide, when considered necessary, maps of the campus or neighborhood in which meetings are held.
11. In planning the menus of luncheons and dinners, to provide, as far as possible, for the special needs of those members who, because of religious or other limitations, may prefer foods other than those ordinarily served.
12. To make special arrangements, when necessary, for the care of colored members of the Academy and the Junior Academy.
13. To cooperate with the Secretary and Treasurer in the sending out of preliminary and final notices of meetings and to have all program material prepared, published, and mailed out at least one week before a meeting.

Divisional Chairman

1. To preside over the meetings of his division.
2. To appoint a divisional nominating committee who will recommend candidates for the office of divisional chairman for the following year. This does not preclude nominations from the floor.
3. To see that his successor is elected by his division for the next year's meetings of his division, and to report such successor's name to the Chairman of the Nominations Committee immediately after the close of the divisional meeting so that the election of his successor may be confirmed by the Academy in general session.
4. To receive all titles and abstracts of papers submitted for presentation at the divisional meetings and to select the papers for the program of the division. The program is then to be turned over promptly to the Chairman of the Program Committee. Abstracts should be received in triplicate, and one copy of each abstract should be sent to the Editor of the Proceedings, one copy to the Press Secretary, and the third copy to the Chairman of the Research Committee with any comments as to its value for consideration for worthy mention. These abstracts should be sent promptly to the above mentioned officers.
5. It is recommended that the divisional chairman present an address, not to exceed thirty minutes in length, before the forenoon meeting of the division over which he presides.

Chairman of the Research Committee

1. To have charge of all research projects of the Academy.
2. To receive all applications for research grants, and to report to the Academy all such recommendations as the Research Committee may make.
3. To receive from the divisional chairmen abstracts of all papers to be presented before the various divisional meetings of the Academy, and from the Chairman of the

Program Committee abstracts of papers to be presented at the General Meeting of the Academy. The Research Committee will use these abstracts as an aid in the determination of such papers as may be deemed worthy of honorable mention.

4. To appoint referees or judges in each division, who will report on the relative merits of the papers presented before the division as a final means of determining the paper or papers deemed most worthy of honorable mention for that division.

5. To report at the dinner meeting the names of the authors of the papers considered worthy of honorable mention, as determined by the Research Committee.

Chairman of the Nominations Committee

1. It is important that the officers of the Academy be members who are sincerely interested in the work of the Academy. They should possess some executive ability and they should be dignified and temperamentally fitted for the positions for which they are nominated. The Chairman of the Nominations Committee should be familiar with the names of past presidents, which may be secured from certain past Proceedings or from the Secretary. The officers to be chosen are President, Vice-President, Secretary, Treasurer, Editor of the Proceedings, Press Secretary, Trustees of the Academy Foundation, and members of Committee for Bonding Trustees. The first six officers are chosen annually. The other officers are chosen only as the terms of incumbent officers expire. The nominations of the first seven officers are made at the dinner meeting or the general session following it. The members of the Committee for Bonding Trustees are appointed by the Executive Committee, and such nominations should be made at the Winter Meeting of the Executive Committee.

2. The Chairman of the Nominations Committee should receive the nominations for Fellows and Honorary Fellows previous to the annual Winter Meeting of the Executive Committee. The Nominations Committee then submits its recommendations to the Executive Committee at the annual Winter Meeting. The maximum number of Fellows that may be elected in any one year is five. Members of the Academy who may have been elected Fellows in the American Association for the Advancement of Science automatically become Fellows of the Academy.

3. Following the close of the divisional meetings, the Chairman of the Nominations Committee will receive from the incumbent chairman of each division the name of the member of that division nominated for divisional chairman for the coming year. The nominations of these divisional chairmen are presented at the dinner meeting, along with the nominations of other officers, by the Chairman of the Nominations Committee.

4. Immediately following the election, the Chairman of the Nominations Committee should file a list of the officers nominated with the Secretary and the Press Secretary.

Chairman of the Invitations Committee

1. To receive the invitations of institutions desiring to entertain the Academy at its next annual Winter Meeting, and to report the recommendations of the Committee at the dinner meeting.

Chairman of the Resolutions Committee

1. To prepare resolutions for courtesies extended by host institutions and local committees.

2. To prepare any other resolutions required by the Academy, through special action of the Academy.

3. To present these resolutions at the dinner meeting of the Academy.

4. To file a copy of each resolution with the Secretary.



JUNIOR ACADEMY OF SCIENCE

Officers for 1938:

President: ELOISE CROSBY, North Side High School, Ft. Wayne.

Vice-President: DONALD FRIER, West Lafayette High School.

Secretary: JAMES BELTZ, Elmhurst High School, Ft. Wayne.

PROGRAM OF EIGHTH ANNUAL MEETING

November 5, 1938

10:00—General session. David Williams, Sciemus Club, Valparaiso, presided.

10:30—Bubbles program by Eiffel G. Plasterer and party.

11:00—Short papers by members:

“Photography,” Robert Weiss, Sciemus Club, Valparaiso.

“Setting Up a Home Laboratory,” Roy Harlow, Sciemus Club.

“Ecology of a High School Nature Preserve,” Grace LaMar and Esther Rainey, Nature Study Club, Technical High School, Indianapolis.

11:30—Business session—Election of officers.

1:00—Principal address:

“A College Girl’s Adventures as a Naturalist on the Barren Grounds of the Arctic,” Mrs. Marguerite Baumgartner, East Lansing, Michigan.

2:00—Short papers by members:

“Bee Culture,” Dorothy Barnhart, Science Club, Wabash.

“Incubation of American Woodcocks,” Madge Norwood, Science Club, Wabash.

“How to Make an Insect Collection,” Evelyn Lachowicz, Biology Club, Lew Wallace High School, Gary.

“Sexuality in Thallophtyes,” Howard Morris, Science Club, Bloomington.

“Commercial Beekeeping,” Jules O. Hendricks, Science Club, Bloomington.

“Distillation of Wood,” Ellwood May, Science Club, Mishawaka. Other papers.

Reports on progress of the Indiana Junior Academy of Science in 1938, Dean Howard E. Enders, Purdue University.

MINUTES OF BUSINESS SESSION

The Indiana Junior Academy of Science held its eighth annual meeting in the Stanley Coulter Hall, Purdue University, November 5, 1938, with David Williams, of the Sciemus Club of Valparaiso High School, presiding.

Officers elected for 1939 were: *President*, Eloise Crosby, North Side High School, Ft. Wayne; *Vice-President*, Donald Frier, West Lafayette High School; *Secretary*, James Beltz, Elmhurst High School, Ft. Wayne.

Mr. J. H. Otto, George Washington High School, Indianapolis, was chosen as successor to G. W. Wade, Crispus Attucks High School, Indianapolis, to serve as a member of the Council from 1938 to 1943. (The other members of the council are: C. O. Pauley, 1934-1939; F. J. Breeze, 1935-1940; Anna Inskip, 1936-1941; and Lola Lemon, 1937-1942.)

The attendance of members and sponsors totalled 265.

The meeting adjourned at 4 p. m.

DAVID WILLIAMS, *President*,

MARY PENROD, *Secretary*.

EXHIBITS

The exhibits were installed early Saturday morning in the General Biology Laboratory, every table in the room devoted to exhibits from the several clubs. Keen interest was manifested by members of the visiting clubs as well as by those who demonstrated their own exhibits.

The following exhibits were prepared:

1. Nature Study Club, Technical H. S., Indianapolis, C. F. Cox, Sponsor: 15 pictures; 4 paintings; 15 herbarium sheets; flower calendar of Nature Preserve.

2. Nature Study Club, North Side, Ft. Wayne H. S., Vesta Thompson and H. S. Michaud, Sponsors: herbarium book; scrap book; moss terrarium; insect collection; potatoes raised as club project.

3. Science Club, Bloomington H. S., M. M. Williams, Sponsor: aeroplane with motor (demonstration).

4. Science Club, Mishawaka H. S., Darl F. Wood, Sponsor: distillation of wood, showing still, etc.; apparatus to liquefy ammonia; sodium atom; burnt wood drawings.

5. Science Club, Lowell H. S., R. J. Brannock, Sponsor: insect collection.

6. Science Club, Wabash H. S., R. D. Black, Sponsor: photomicrographs; snakes; radio actuated by electronic cell (demonstration).

7. West Lafayette High School Science Club, Anna Inskip, Sponsor: soils; stamp collection; 3 varieties of Bryophyllum; wild flowers (Rocky Mt. Region); crystal oscillator; communications; anatomical plaster paris molds and casts; steps in polishing gems; gems; projects in enlarging photos.

8. Science Club, George Wahington H. S., Indianapolis, J. H. Otto, Sponsor: leaves; rocks; minerals.

9. Geography Council, North Side H. S., Ft. Wayne, F. J. Breeze, Sponsor: large map showing utilization of land along Hayden Rd.

10. Biology Club, Lew Wallace H. S., Gary, Lola Lemon, Sponsor: 12 leaf herbarium books; 7 insect collections.

11. Sciemus Clubs, Valparaiso H. S., C. O. Pauley, Sponsor: static machine (demonstration); aeroplane; polariscope; arc light; light detector; fluorescence under ultra-violet rays.

12. Shortridge Chemistry Club, Indianapolis, Lois Martin, Sponsor: not displayed.

JUNIOR ACADEMIES OF SCIENCE

Town	Club	Date of Affiliation	Sponsor
North Madison	*Hilltop Nature Study Club	1931	A. J. Slaton
Valparaiso	*Sciemus Club	1931	C. O. Pauley
Bloomington	*General Science Club	1931	M. M. Williams
Indianapolis	*Biology Club	1931	C. E. Ransom
Crispus Attucks			
Crawfordsville	*Audubon Society	1931	Emmett Stout
Indianapolis	*Chemistry Club	1931	Lois Martin
Shortridge			
Union City	*Science Club (inactive)	1932	
Indianapolis	*Nature Study Club	1932	C. F. Cox
Technical			
Coosse	*Jolly Hiking and Nature Club	1932	Chas. Luther (No report)
(Whitley County)	Wash. Center Hiking and Nature	1932	(No report)
Anderson	Science	1936	M. J. Brozier
Bloomington		1938	W. B. Miner
University School			
Cambridge City	Tri Science	1934	J. L. Bozarth
East Chicago	Edison	1935	Harry Apostle
Roosevelt			
Ft. Wayne	Phy-Chem	1937	Ruth Wimmer
Elinhurst			
Ft. Wayne	Geography Council	1932	F. J. Breeze
North Side	Science	1936	Vesta Thompson and H. H. Michaud
	Phy Chem	1936	H. A. Thomas
Gary	Biology	1935	Lola Lemon
Lew Wallace			
Gae City	Science	1936	Roy McKee
Greencastle	Science	1936	F. N. Jones
Guilford	Science	1936	
Hammond	Nature Loro	1937	H. J. Bjorklund
Thos. Edison			
Indianapolis	Science	1937	J. H. Otto
Geo. Wash.			
Lowell	Science	1935	C. N. Seeright
Madison		1936	Evans Cottman
Marion	Science	1936	Mrs. Pauline Mayhugh
Mishawaka	Science	1936	Darl F. Wood
Montmorenci	Jr. Acad. of Sci.	1933	I. W. Vance
Mooreville	Science	1936	Fitzhugh Lee
Muncie	Science	1934	F. Kyger
Blaine Jr.			
New Albany	Jr. Acad.	1935	Gladys Knott
Paoli	Science	1935	O. R. Whitlock
Tipton	Jr. Science	1933	W. D. Hiatt
Wabash	Science	1936	R. D. Black
West Lafayette	Science	1938	Anna Inakeep

*Charter members.

MEETINGS OF RELATED GROUPS

Following the precedent of former years, the members interested in entomology and systematic botany held informal meetings at the fall meeting on Saturday forenoon, November 5.

Entomology.—The meeting was called to order at 9 o'clock by Philip Luginbill, chairman. Thirty-three attended this session.

Informal discussions took place on various subjects of interest to economic entomologists, such as Corn Earworm Investigations, by E. V. Walter; Cutworm Studies and Corn Borer Investigations, by G. A. Ficht; Forest Insect Investigations, by B. A. Montgomery; Hessian Fly Studies, by Curtis Benton; and White Grub Investigations by Philip Luginbill. All these discussions aroused considerable interest.

The latter part of the period was taken up by G. E. Gould, who showed some films on the development of cockroaches and activities of other insects.

P. T. Ulman, Indiana Department of Conservation, was elected chairman of the group for 1939.

Taxonomy.—The meeting of the plant taxonomists was called to order by Ralph M. Kriebel, chairman. About 40 attended the discussion.

The meeting was devoted to a symposium on the concept of the species, the discussion being centered about the following four topics: History of the Concept of the Species, by Theodore Just; The species Problem from the Standpoint of the Taxonomist, by Ray C. Friesner; The Use of the Species Concept in Mycology, by Marion L. Lohman; and The Genetic Interpretation of the Species, by Alfred C. Kinsey.

There was a report on the field trip held in the Kankakee region, September 2-5, 1938, supplemented by Kodachrome slides of photographs taken in the field during the meeting.

It was decided to have another summer field trip in 1939 in southwestern Indiana. Scott McCoy and Chas. C. Deam were appointed as a committee to make arrangements.

Fred A. Loew, Huntington College, was elected chairman for 1939.

NEW MEMBERS 1938

Ackerson, Oscar E., 1711 O Street, Bedford.
Belcher, Robert Orange, 224 Waldron Street, West Lafayette.
Betz, Howard T., Valparaiso University, Valparaiso.
Biefeld, Dr. L. P., Purdue University, Lafayette.
Brundage, Roy Charles, Agri. Exp. Station, Purdue University,
Lafayette.
Bryant, Carl C., 1312 Ferry Street, Lafayette.
Campbell, Dr. Kenneth Nielsen, 614 N. St. Peter Street, South Bend.
Cleland, Prof. Ralph Erskine, Indiana University, Bloomington.
Craig, Johnston C., 515 Lincoln Avenue, Bedford.
Daily, William A., 3216 Ralston Avenue, Indianapolis.
Danielson, Gordon Charles, Dept. of Physics, Purdue University,
Lafayette.
Duncan, Robert Ferrie, 143 South Grant, West Lafayette.
Dutro, Miss Ruth, Hagerstown.
Echelbarger, Garold Hungerford, R. R. 1, Jonesboro.
Falkenberg, Dr. G. V., Purdue University, Lafayette.
Fitzgerald, Dr. Dorothea, St. Mary-of-the-Woods.
Fulwider, C. O., 617 W. Washington Avenue, South Bend.
Gantz, Dr. Edward S., 106 W. Jefferson Street, Crawfordsville.
Gasho, Miss Grace Anne, R. R. 2, Atlanta.
Gault, Hugh Richard, Ravinia, Illinois.
Geiger, Howard Eugene, Purdue University, Lafayette.
Hamill, Dr. William H., University of Notre Dame, Notre Dame.
Hartman, Dr. John D., Purdue University, Lafayette.
Henion, Miss Ruth E., Purdue University, Lafayette.
Hilbert, Miss Marguerite, 5868 N. New Jersey Street, Indianapolis.
Hines, George Ernst, Jr., Ulen Country Club Park, Lebanon.
Hopp, William Beecher, 1411 Maple Avenue, Terre Haute.
Hovda, Dr. Olaf, 519 S. Rotherwood Avenue, Evansville.
Howick, Prof. Harry, 403 N. College Avenue, Muncie.
Huffman, Mrs. Elna, 122 Waldron, West Lafayette.
Ignatia, Sister, St. Mary-of-the-Woods.
Johnson, Dr. David F., Indiana State Teachers College, Terre Haute.
Kase, John Charles, Purdue University, Lafayette.
Kent, Robert E., 198 State Street, Franklin.
Kesling, Robert Vernon, Peru.
Klinge, Paul Ernest, 3365 N. Colorado Avenue, Indianapolis.
Koepper, James M., Medora.
Lee, Hugh B., 1522 S. Center Street, Terre Haute.
Long, R. E., 604 Harrison Avenue, South Bend.
Longden, Grafton J., Jr., Broadview Farm, Greencastle.
Luginbill, Dr. Philip, 107 Fowler Avenue, West Lafayette.

Mauzy, Jack, 218 Pearl Street, Jeffersonville.
Maxwell, Dr. Roy D., Ball State Teachers College, Muncie.
Mitchell, Prof. Allan Charles G., Indiana University, Bloomington.
Murray, Herbert C., 106 W. Lutz Street, West Lafayette.
Overman, Richard R., Longden Hall, DePauw University, Greencastle.
Richards, Miss Ruth R., 3935 Graceland Avenue, Indianapolis.
Ryan, George S., 614 West South Street, Angola.
Serviss, Prof. Fred LeVerne, 136 East Stadium Avenue, Lafayette.
Shaw, Thomas Edward, 206 W. Lutz Avenue, West Lafayette.
Shockley, Clarence Herbert, 924 Woodlawn Avenue, Terre Haute.
Strickler, Dr. P. M., Indiana Central College, Indianapolis.
Summers, S. D., 514 W. Prospect, Angola.
Templeton, Miss Margaret, 898 E. Jefferson Street, Franklin.
Terry, Robert Lee, 6536 Irving Avenue, Merchantville, New Jersey.
Thomas, Dr. Ancil R., 831 Laporte Avenue, Valparaiso.
Thomas, H. Rex, Purdue University, Lafayette.
Thrun, Dr. Walter E., Valparaiso University, Valparaiso.
Tussing, Lyle, 619 Salisbury, West Lafayette.
Uyl, Prof. Daniel Den, Purdue University, Lafayette.
Van Camp, John Lloyd, 226 Lincoln Street, West Lafayette.
Wean, Robert Eugene, Purdue University, Lafayette.
Weimer, Dr. Harry Raymond, Manchester College, North Manchester.
White, Francis M., 6529 Woodlawn Avenue, Chicago, Ill.
Whitmore, Robert, Zionsville.
Wright, Dr. William Lee, 208 E. 46th Street, Indianapolis.

NEW JUNIOR CLUBS 1938

Junior Academy Club of University School, Indiana University,
Bloomington.
Madison High School Science Club, Madison.

FELLOWS ELECTED 1938

Beghtel, Dr. F. E., Evansville College, Evansville.
Graham, Prof. F. V., Ball State Teachers College, Muncie.
Kriebel, Dr. Ralph, Soil Conservation Service, Bedford.
Smith, Dr. B. H., Indiana State Teachers College, Terre Haute.
Thornbury, Dr. W. D., Indiana University, Bloomington.

HONORARY FELLOW, ELECTED 1938

Arthur, Dr. Joseph Charles, Purdue University, Lafayette.

NECROLOGY

SISTER AMATA (ROSALIE MCGLYNN)

Chicago, Illinois
July 23, 1891

St. Mary-of-the-Woods
April 2, 1937

For several years, Sister Amata McGlynn had linked her life with that of Saint Mary-of-the-Woods College. Particularly solicitous was she about the freshmen of Guerin Hall, whose training and direction, in her office as class adviser, she had eminently carried on. Their interests were her interests; their joys and sorrows were alike hers. Neither did her guiding influence cease with each succeeding class; it passed on contin-



SISTER AMATA

uously until each student gained senior rank and later on achieved a role in the drama of life. Sister Amata closely directed freshman extra-curricular activities, keeping always in view the highest ideals. In the scholastic calendar many events reveal Sister Amata as an organizer, a leader of exceptional merit.

In the lecture room Sister Amata was a master in her fields—chemistry and mathematics. She, with knowledge at her finger-tips, was a teacher par excellence. In 1929, for her work in chemistry, she received the degree Doctor of Philosophy from Indiana University and was elected

to the Society of the Sigma Xi. Closely associated with the Chemistry Department of the college, the Curie Club, composed of the majors and the minors in chemistry, found Sister Amata a competent director in its experimental work and its various lecture programs. Her scholarly interest disclosed itself also in her active memberships in the Indiana Academy of Science, the American Association for the Advancement of Science, and the American Chemical Society.—*From a memorial in the Saint Mary-of-the-Woods Alumnae News, 12:21-22. 1937.*

WILLIAM BEBB

Rockford, Illinois
June 15, 1869

Spencer, Indiana
April 7, 1938

Dr. William Bebb was one of a large family, many members of which had a deep interest in plant life. His father was known over the world for his work on the taxonomy of the willows, and many of the famous botanists of the time visited the Bebb home at Rockford, Illinois.

After graduation from the Chicago College of Dental Surgery, Dr. Bebb practiced his profession for a time in Chicago, but his broader interest in dentistry soon called him into the field of teaching and research. From 1902 to 1914 he served the Dental College of the University of Southern California as librarian, secretary, and teacher, began collection of material for a museum of comparative dental anatomy, and assisted in the reorganization of the Southern California Dental Association.

In 1914 he transferred to Northwestern University and undertook the development of the museum and library of the dental school. This work later took him to Europe, where he secured a large collection of books and engravings. This material, with other collections secured in America, forms the nucleus of the present museum and library of the school.

In his later years Dr. Bebb spent a great deal of time and effort in the development of a summer home near Lauderdale Lake in Wisconsin. His interest in the study of the interplay of native and introduced species and their environment led to his withdrawal from his position at Northwestern in 1927.

Later an opportunity was offered for him to continue his work as a naturalist at the McCormick's Creek State Park, near Spencer, Indiana, where he created the now popular Trail Side Museum. At the park he lived during the summer in a little group of tents, a model camp, with feeding stations for birds and small animals. It was only in camps like this that he was wholly at home and at his best, whether in Indiana, the High Sierras, California, Wisconsin, or elsewhere.

In his numerous trips to and from California he made extensive studies of the destructive effects of the automobile on bird and animal life.

The Dental Index of Periodical Literature lists Dr. Bebb fifty-one times, the greater number of his publications dealing with comparative dental anatomy. He also wrote many notes on various phases of natural history.—*Written from material supplied by E. H. Hatton, Northwestern University.*

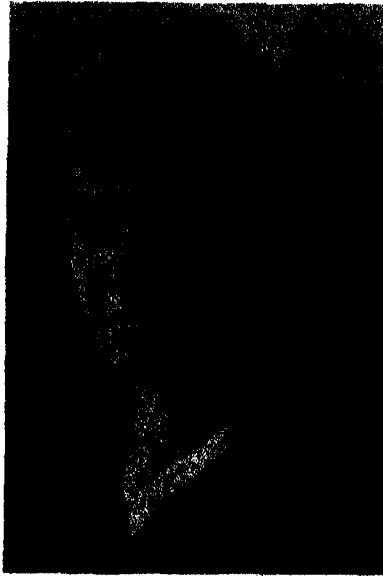
KATHERINE GOLDEN BITTING

Stratford, Ontario, Canada
April 29, 1869

San Francisco, California
October 15, 1937

Katherine Golden Bitting received her Bachelor of Science degree at Purdue, 1890, Master of Science, 1892, and Doctor of Science, 1935.

She was assistant botanist, Indiana Experiment Station, 1890-1893; instructor in biology, Purdue, 1893-1901; assistant professor, Purdue, 1901-1904; microanalyst, Bureau of Chemistry, U. S. Department of Agriculture, 1907-1913; technician, National Canners Association, 1913-1918; member, Subsistence Division of the Q.M.C., 1918-1919; bacteriologist, Glass Container Association, 1919-1923. She was fellow of the



KATHERINE GOLDEN BITTING

A.A.A.S. and the Indiana Academy of Science and a member of the Botanical Society, American Society of Bacteriologists, and the California Academy of Science.

Dr. Bitting's adult life was spent in research. Her specialty was micro-organisms of preserved foods. She was a distinguished botanist and microanalyst, specializing on molds and micro-organisms involved in the preparation and preservation of food. In collaboration with her husband, Dr. A. W. Bitting, who survives her, also a noted specialist in foods, she published extensively on joint researches.

A list of research articles includes 45 titles ranging from papers in scientific journals to monographs and bound volumes. Her last manuscript, soon to be published, is a bibliography on gastronomy in which over five thousand publications in various languages had been considered.

This probably will be the most comprehensive work in the field. During her residence in this state, she was an active member of the Indiana Academy of Science and contributed numerous papers.

Dr. Bitting was a woman of rare wit and personal charm. She abhorred intellectual indolence and dishonesty in any of their forms, and her scientific work made her an authority in her chosen field.—*John S. Wright.*

CHARLES BROSSMAN

Philadelphia, Pennsylvania
January 17, 1887

Indianapolis, Indiana
June 30, 1937

After his graduation from the Philadelphia Manual Training School, Charles Brossman entered the employ of a manufacturer of scientific instruments. His next work, with the Baldwin Locomotive Works, in Philadelphia, was interrupted by service in the Spanish-American War with the Puerto Rican Expedition as a member of the First Troop, Philadelphia City Cavalry.

At the close of the war he moved to Indianapolis where he was engaged in the design of filtration plant and pumping equipment for the Indianapolis Water Company. At the same time, he had a responsible part in the construction of the filtration plant in Washington, D. C.

In 1904, Mr. Brossman entered the private practice of engineering, opening a consulting office in Indianapolis with Mr. R. P. King. This partnership was dissolved in 1907, and Mr. Brossman continued the consulting practice in his own name. His engineering work centered in the Middle West, notably in Michigan, Illinois, Iowa, Ohio, Kentucky, and Indiana.

As with most young practicing engineers, his earlier work had considerable variety, including design and supervision of construction of factory buildings, asphalt plants, street improvements, and heating and power plants. Gradually, however, as his reputation grew, he specialized in water supply and sewage disposal for cities, towns, and institutions. His career was stopped at its peak by his sudden and untimely death.

Mr. Brossman's activities were extended in generous service to his profession. In addition to his membership in numerous technical and business organizations, he was Secretary of the Indiana Engineering Society for twenty years, and, later, was President of that organization. He also served at various times as an officer of a number of other professional societies.

Not satisfied with his contributions to the up-building of his profession, Mr. Brossman was the author of many articles in the public and technical press, in the publications of the organizations of which he was a member, and of numerous papers presented at engineering meetings. The Ohio Valley floods in January, 1937, added to his burden of engineering engagements, but he still found time to prepare articles for publication on flood-control measures in Indiana.

His interests were by no means confined to his professional work but were carried into the life of the community in which he made his home. At the time of his death, Mr. Brossman was Chairman of the

Boys Work Committee of the Indianapolis Rotary, an incident in his busy life, but in itself indicative of his widespread interest in the people about him.

Socially, he was genial companion, possessed of a rare sense of humor and full of sparkling fun. A man of unimpeachable integrity, his code of professional ethics was exceptionally high. His varied interests and his willingness to serve made him an unusually active and useful citizen, as well as an honor to his profession.

In 1903 he was married to Mary Edith Dean, of Indianapolis. His widow and three children, Charles Dean Brossman, Mrs. Francis (Brossman) Meyer, and Mrs. Frank (Brossman) Parish, survive him.—*Condensed from Memoirs of the American Society of Civil Engineers.*

FRED DONAGHY

Ossian, Indiana
March 3, 1879

Terre Haute, Indiana
July 8, 1938

Fred Donaghy was born on a farm near Ossian, Indiana, on March 3, 1879, and died while in service as Professor of Physiology and Hygiene at Indiana State Teachers College on July 8, 1938. He received his elementary education at Ossian and graduated from the high school in 1898. Shortly thereafter he entered the Indiana State Normal School at Terre Haute and, after receiving sufficient training, became a teacher in the elementary schools of Indiana.



FRED DONAGHY

Upon graduation from Indiana State Teachers College in 1912 he was honored with a scholarship at Indiana University and received his Master's Degree from that institution in 1915.

Shortly after his graduation from Indiana State Teachers College, he became connected with that institution as instructor, and, save for the time that he was on leave of absence pursuing graduate work and in the service of the United States army during the World War, he remained there until the time of his death, serving as instructor, assistant professor, associate professor, and professor of biology and physiology. During the last ten years of his professorship he was in charge of the work in physiology and hygiene, and in that capacity he endeared him-

self to a great number of young men and women who were entering the teaching profession and the field of medicine.

In 1926 he secured a leave of absence from the institution to accept a fellowship at Johns Hopkins University and work toward the doctorate. The degree was conferred in 1928, and Dr. Donaghy returned to continue his work as professor of physiology and hygiene.

Dr. Donaghy's dissertation for the master's degree, "The morphology of *Riccia fluitans*," was published in the Proceedings of the Indiana Academy of Science in 1916, and that for the doctor's degree, "Studies in immunity to transplantable tumor," was published in 1930 in the American Journal of Public Health.

While at Johns Hopkins University he was elected to Sigma Xi. He became a member of the Indiana Academy of Science in 1918 and was elected fellow in 1930.

Dr. Donaghy was known to his colleagues and his students as a sincere teacher and an untiring worker. In addition to the work which he carried on as professor of physiology he was a tireless worker with flowers. At the time of his death he had two beautiful gardens at North Terre Haute in which he spent all of his spare time, and it was while working in one of these gardens that the attack resulting in a cerebral hemorrhage occurred.

It may be said without exaggeration that the death of Dr. Donaghy was one of the most severe shocks Indiana State has had in recent years. In addition to being a great teacher, he was a great leader of young men and women. There are hundreds of young people in Indiana and throughout the United States who will remember him and cherish his excellent advice and words of encouragement. He was instrumental in procuring scholarships and fellowships in leading universities for many young men in his classes. A great many of these young people were helped not only in a spiritual manner but in a financial manner as well. Dr. Donaghy spent a great part of his salary on the two hobbies in which he was interested, his garden and young people.

His spirit will live on in Science Hall at Indiana State, where he is now commemorated by an inspiring mural in the main hall painted by one of his most ardent admirers, Gilbert Wilson.—*James F. Mackell.*

JOSEPH P. NAYLOR

Pennsville, Ohio

April 4, 1853

Little Rock, Arkansas

May 22, 1938

With the passing of Professor Joseph P. Naylor at Little Rock, Arkansas, the Academy lost one of its few remaining charter members and one of its past presidents. Professor Naylor was born near Pennsville, Ohio, but came to Indiana early in life. Receiving the master of science degree from Indiana University in 1885, he was a professor of physics from 1885 to 1891. He became head of the Department of Physics at DePauw University in 1891, when DePauw was the largest university in the state, and remained until his retirement as emeritus professor in 1925. During the past few years he lived with a daughter in Little Rock, Arkansas. Another daughter also survives him.

Professor Naylor was a man of fine personality and broad interests. A trained and skillful technician, he constructed much fine and delicate apparatus most of which is still in use at DePauw today. Deeply interested in botany, he made a fine collection of mosses which he presented to the Department of Botany at the time of his retirement. As an excellent and inspiring teacher, he trained a number of students who have since become outstanding in physics. He was active in church work and was director of a church choir for many years.



JOSEPH P. NAYLOR

As long as he remained in Indiana Professor Naylor was active in Academy affairs, serving as president in 1912. He was a founder and a president of the Indiana Association of Physics Teachers, a member of Phi Beta Kappa, and a fellow of the American Physical Society.

Joseph P. Naylor was one of that splendid group of early Indiana scientists which included David Starr Jordan, John M. Coulter, John C. Branner, and Harvey W. Wiley, and in his death Indiana loses another one of its distinguished men who contributed much to the scientific progress and standing of the state.—*Will E. Edington.*

PRESIDENTIAL ADDRESS

A Plan for Accomplishing More Effective Research

ELI LILLY, Indianapolis

It takes a large amount of self-assurance for a person who has nothing more on his watch chain than a magnifying glass to attempt, in the words of a picturesque Hoosier idiom, "to teach his grandmother to suck eggs," and yet, certain experiences in the executive direction of some important pieces of research and the exigencies of the occasion possibly justify his taking some liberties.

In January of this year, an investigation on "Creative and Research Work in the Undergraduate College of Liberal Arts," conducted by DePauw University, revealed that in two-thirds of sixty-five of America's most important educational institutions conducting investigations of an advanced order, there were no central committees to consider and coördinate the work. In the remaining third, it is quite evident that in only a very few cases was the vital importance of proper coördination and coöperation recognized.

In the great majority of colleges, research is carried on by what might be called the "Departmental Pigeonhole System," that is, a single able professor with a few assistants and a small number of students bury themselves in the gloomy recesses of a single department, heedlessly avoiding the sparkling sunlight of collateral branches of knowledge and the cross-fertilization of ideas from the pollens borne on the fragrant breezes of the upper air. Rarely, if ever, can an investigation be properly confined to problems within the scope of a single department, and yet, in an overwhelming majority of cases we find pieces of research being planted amidst bleak surroundings where one or several life-giving elements vital to its full-flowering are sadly lacking.

The Departmental Pigeonhole System was at its highest peak in the days of the alchemists who worked in secret and kept their records in private codes, thus greatly delaying important chemical discoveries.

In China, a man who has a limited amount of knowledge is compared to a person sitting at the bottom of a well; the sky appears very small to him. In the ramification and specialization of modern sciences, we who specialize in one well find ourselves much in the position of the Chinese gentleman—our lines of vision do not diverge much from the mouth of our own particular well. It is necessary, therefore, that we join hands, pull ourselves to an elevated level, and see the horizon.

The logical way of starting an inquiry in any organization is to call together an enthusiastic group of men who know about the subject from as many viewpoints as possible. When this is done, scant respect can be paid to chilling academic departmental boundaries, but the brilliant results of such coöperation speak for themselves. Who would expect a surveyor to make a map if he were required never to move from one spot? It is just as reasonable to expect to explore thoroughly a complicated question from only one direction. Yet how great is the majority of research workers who have ignored this perfectly apparent truth. It has been a blind spot in our procedures.

Securing effective joint action between investigators in different departments calls for an excursion into the humanities. It cannot be accomplished by cracking together the heads of research men with the peremptory command, "Coöperate!" It requires long and careful preparation and presupposes that the head of the university is sympathetic to scientific inquiry and commands the respect and loyalty of his deans and that they have confidence and trust in one another, in short, that the *esprit de corps* of the institution is high. Unless you have this firm basis to build upon, time and effort will be wasted.

It is not as though coöperation were a brand new project with this Academy, for our Biological Survey may be mentioned as a successful instance of the value of working together. At the Indianapolis meeting of the American Association for the Advancement of Science last December, there was evident a heartening tendency for the various sections of the sciences to consult and advise with one another.

Dating by tree rings, to the very year of the building of a great number of the pueblos in the Southwest, is a most outstanding and brilliant example of the coöperation of astronomers, botanists, meteorologists, and archeologists.

The spirit of joint participation in well-planned research has been brilliantly developed in the great organization that we have the honor of visiting today. The morale of its staff has been of the highest order for years, so the proper elements for the development of coöperative work were present. Ten years ago the Purdue Research Foundation was formed and was fortunate enough to secure the services of a "catalyzer" who knew his humanities and under whose careful nurture the plant has grown to symmetrical and beautiful proportions.

At the beginning, a delicate touch was required, and the first activity was simply a survey which revealed that the faculty were conducting a surprising number of worthy projects, the existence of which had been hitherto generally unknown. Some of these pieces of work were more or less duplications, and there were frequent overlappings. Adroit and sympathetic suggestions with a sprinkling of spiritual and financial encouragement extending over a period of months was all that was needed to convince the staff that great good follows the liberal and generous exchange of ideas in research work. Since the professorial staff must be the inspiration of all original work, care was taken not to invade the chosen fields of professors who had long been conducting successful investigations. Their work was reënforced by additional funds and encouragement. The Purdue Research Foundation has grown to be one of the most successful centers of research in the country.

An objection might be raised as to the great difficulty to be encountered in the proper division of scientific credit and of financial return in coöperative work. We are apt to build up in our minds the horrid image of a flashing sword poised above the research baby in a desperate effort to discover its real parent. This is a bogey easily banished by mutual confidence and fair and impartial supervision. Under such conditions it has proved to be a trivial danger as compared with the great gain in power of accomplishment. The allocation of credit has long been solved by scientific men by the lists and order of their

names upon publications. Even in cases where temporary misunderstandings have been engendered, time, the great impartial umpire, has given the credit to whom it was due. The public cannot be fooled forever.

The division of financial returns resulting from royalties is handled in several ways by different universities. In a few, as in Harvard, nothing is patented and no royalties taken. This policy seems a wasteful one, for royalties create a fund for financing further inquiries. In some institutions, like the University of California, the attitude is to leave the University out of consideration altogether and to allow the professors to take out patents and handle the royalties as they see fit. In an increasingly growing number of research centers, however, the royalties are being used for further investigation. In the case of a university research organization, a very fair division would be: one-third of the royalty to be given the personnel involved, one-third to be plowed back into the general research fund, and one-third to be used for further work upon the project yielding the royalty.

While admitting the value of allied work in research in the applied sciences, a very natural mental reservation might occur as to its possibilities in original work in other fields. This doubt may be dispelled by a review of the usual departments found in leading universities and colleges. Take for instance philosophy, psychology, religion, political science, and political economy. Each one of these branches of knowledge should be used, individually and collectively, to triangulate upon the most vitally important questions of the day. Combined, they would be much stronger than if used alone—remember the old fable of the bundle of sticks.

Again the question might be raised as to what chance any of such studies have to gain financial encouragement, especially from business institutions. The answer is that the opportunity is here, or should be, for what is more important than the manifold personnel problems that face our civilization? Forward-looking businesses are employing psychologists and psychiatrists to develop the understanding of executives and to reëducate faulty reaction-mechanisms in individuals needing it. The one most important duty of the head of any organization is to develop and to stimulate the human material within it, for if the personnel is able and enthusiastic and of high morale, the work of the institution takes care of itself. Its success is assured. If its human material is not happy and enthusiastic and is ill-trained and dull, nothing on earth can save it. Do we dare say there is no chance for collaboration in research here?

That our spiritual development has a hundred-year lag behind our material progress is a trite statement. Several years ago Edward Filene, of Boston, warned business with the pregnant words, "Research or Bust." Are not the same words appropriate for those of our educators and religious guides whose efforts are so far behind the times? They need all the power they can borrow, beg, or steal to stem the tide of materialism engulfing the world and to teach all humanity that it is not what we have but what we are that is of real importance. We must be taught that the imponderables are vital—radiant personality, intense love of fine and beautiful things, honor, courtesy, etc. Our attention must be

taken from the gross, materialistic philosophy which occupies so many today to the exclusion of practically everything else. Greed in all quarters (and it is found in *all* quarters) should be attacked by the most powerfully allied groups of authorities that can be called to the colors. No chance for a coalition of talent here? Why, the very sky is the limit! Much important work along these lines is going on at the University of Iowa, but theirs is almost a voice crying in a dismal wilderness.

Let us mention a few other subjects selected almost at random, such as, law, sociology, history, languages, literature. There is not one of these fields which cannot be enriched by knowledge and insight gained from the others. Mathematics is the background and final arbiter in almost any field of knowledge. Not long ago I heard an outstanding scientist say that Dr. Irving Langmuir could prove mathematically what most highly trained men could just barely imagine!

The pioneer work of the Purdue Research Foundation has been followed very closely by Ohio State at Columbus. The Wisconsin University Departments of Medicine, Agriculture, and Chemistry have proved the great value of working together upon many of their problems. At the University of Iowa the spirit is growing, and we are wondering what relationship this spirit has to the notable development of a new school of American Art there. The Harvard Medical School is concentrating upon the problem of proper coördination in its pioneer work.

The next step in the "orchestration" of research will be the pooling of efforts by separate organizations. This will be more difficult than winning success in the various individual institutions. Let us hope that it will never be carried as far as by some individuals and universities in some foreign nations, where to every intent and purpose some center announces that its members are working in a certain field and all outsiders are warned not to trespass! In the coöperation of twelve of our agricultural schools in the cultivation of corn may be seen the dawn of this further coördination of experimental work. The Northeastern Agricultural Experiment Stations have appointed each director a referee for the guidance of investigation in one field. In astronomy, more perhaps than in any other field of knowledge, due to the relatively small number of important centers, the research work is organized, coördinated, and unified.

For more than a century, Indiana has been associated with men eminent in science. The founders of this Academy included a number of international fame in their respective fields. During the last fifty years, members of this organization have done much to enlarge the boundaries of knowledge, and there is enough high talent in this room today, if thoroughly coördinated, to cause Indiana to become a "center of white-hot spiritual energy." The free exchange of opinion, interaction of imagination, cross-fertilization of ideas, and the pooling of wisdom will cause the maximal utilization of human effort, the elimination of unnecessary duplication, and a great increase in results. Properly coöperative research work is synergistic and does not increase in success by arithmetical but by geometrical progression. Steps to secure its adoption by our educational bodies is the one greatest opportunity lying before us.

SECTION ON ARCHEOLOGY

Chairman: GLENN A. BLACK, Indianapolis

The attendance at the meeting was small, and this has raised, in the minds of those interested in the section, the question of enlisting the support of many non-professional students of archeology and anthropology. It is believed that the "hunch of the amateur" may often lead to the solution of technical problems.

Of prime interest to archeologists of Indiana is the announcement that the Indiana Historical Society has, through purchase, saved from destruction the most famous archeological site in Indiana, namely, the Angel Mounds, located a few miles east of Evansville. It is planned at an early date to explore the site and to restore the mounds, as far as possible, to the condition in which they were occupied by the Indians.

Mr. Paul Weer, who is engaged in ethno-historical work for the Indiana Historical Society, was elected chairman of the section for the coming year.

ABSTRACT

The present status of archeology east of the Mississippi. GLENN A. BLACK, Indiana Historical Society.—The taxonomic method of dealing with archeological cultures has done much to clarify problems of the past. The Mississippi Pattern, with the exception of a postulated Lower Phase, is now rather well defined. The Woodlands, in the Northeast, has been defined for a period suggesting considerable antiquity. In the north central region, the pattern at present appears to apply mainly to tribes of more recent occupation levels. The third pattern, as yet unnamed, presents a far more obstinate problem. Hopewellian, its principal phase, has been and continues to be the bane of all workers in this field. Culturally suggesting a transmutation of Mississippi and Woodlands, the diagnostic traits of each are such as practically to defy relegation. Mississippi traits within the phase are neither Upper nor Middle Mississippi determinants. The Woodlands elements, with the exception of ceramics, do not seem to match too closely those traits defining the Lake Michigan Phase of Woodlands or the aspects within this phase.

As a working hypothesis the suggestion is made that (1) Hopewellian is basically Woodland with many Mississippi elements within it which are neither Upper nor Middle Mississippi; (2) the Mississippi traits within Hopewellian are, in part, diagnostic of a deep south culture group, the identity of which has not yet been made clear; (3) the Woodland traits within Hopewellian, combined with those for the Lake Michigan Phase of Woodlands, will provide a sorely needed chronology and depth for Woodlands within this area; (4) the Copena Complex as found by Webb, the Marksville of the Southeast, and investigations now being carried on in the Gulf region will go far toward solving the question of origin of many elements within the Ohio and Elemental Aspects of Hopewellian. Adena and Hopewellian are far more homogeneous than their present relative placement within the classification indicates. Adena should be considered as a direct aspect of Hopewellian rather than in a separate phase category. Adena, occurring repeatedly at components also productive of Fort Ancient, raises the query as to whether Adena-Hopewellian is late enough and Fort Ancient early enough for there to have been some slight degree of tangency between them. It should be made clear that these suggestions are yet to be tested. Concerted action, resulting from the elimination of the personal element in research, standardization of nomenclature, and systematic classification of culture traits is, however, making such suggestions acceptable to a group, whereas a few years since they would have been considered heretical.

Some Possible Sixteenth and Seventeenth Century Locations of the Shawnee

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Due to the indefinite character of the term *šaawanwa*, which the Shawnee¹ apply to themselves as a tribe, it is extremely difficult to locate the Shawnee with any degree of certainty during the early colonial period. In many Algonquian dialects the Shawnee tribal name *šaawanwa* has cognates meaning "south" or "southerners"; therefore, when Algonquian-speaking peoples refer to a group by a term approximating *šaawanwa*, it is an open question as to whether the Shawnee are meant, specifically, or whether the reference is merely a generic one, applicable to any Algonquian group or groups located to the south of the main body of this stock. In our estimation, however, it seems likely that the name *šaawanwa* or approximations thereto specifically relate to the Shawnee in the majority of our early references. Not only do the Shawnee recognize *šaawanwa* as their tribal name, but various Algonquian and non-Algonquian groups, as well as the English, French, and Spanish, use terms approximating *šaawanwa* in reference to the Shawnee.

Since Mooney sounded his warning note as to the uselessness of theorizing on the location of the Shawnee prior to 1669-70,² a certain amount of new data has appeared which merits discussion as possibly indicating some locations of the Shawnee during the period 1540-1670. These data I wish to review as briefly as possible.

1540.—Evidence for one possible location of that part of the Shawnee tribe known as the *čalakaaba* division is contained in the accounts of De Soto's expedition of 1539-44. While still east of the Blue Ridge, and probably near the headwaters of the Savannah river in what is now western North Carolina, De Soto and his party visited the province of Chalaque. The province was poor and lacking in corn; the inhabitants gathered roots and herbs and shot game with bows and arrows. The people were naked, lean, and unwarlike, and one town in the province gave De Soto's party 700 wild turkeys, with which the country abounded. A chief gave De Soto two deerskins. Garcilaso states that all the "Chalaques" save the old and the blind left their towns when De Soto's party approached and fled to the mountains.³ Mooney and other historians have identified the "Chalaques," "Chelaques," or Achalaques as the Cherokee.⁴ Concerning the identification

¹ The Shawnee are an Algonquian-speaking group prominent during the 18th century in the Ohio Valley region. The tribe comprises five non-totemic, named divisions, to-wit: *čalakaaba*, *čawikila*, *mekoco*, *pekowi*, and *kispoko*. Linguistically the Shawnee are most closely related to Kickapoo, Fox, and Sauk. The Shawnee now number about 1,500 souls, including mixed bloods; they live in three groups in central and northeastern Oklahoma.

² 13, p. 631.

³ 10, p. 24.

⁴ 10, p. 194; 22, p. 204.

of Chalaque, however, Swanton has recently offered an interesting commentary. He says, "It has been usual, and natural, to identify the Chelaque or Xalaque of the De Soto chroniclers with the Cherokee, but if the word Cherokee has the origin I suspect, from Muskogee *chilokee* (there is no *r* in Muskogee), signifying 'people of a different speech', it may not have been applied solely to the Cherokee but as well to other non-Muskogee tribes, such as the Catawba and their allies. If that is the case, the use of the term in the De Soto chronicles does not prove that the Cherokee were then in their historic seats."

This statement by Swanton suggests, of course, an interesting possibility concerning the derivation of the name for the *čalakaθa* division of the Shawnee. Part of this term, *čalakaa*, is unanalyzable in Shawnee and may represent, in borrowed form, the Muskogean term *Chilokee*; the *θa* formative ending of the term is a formal Shawnee suffix designating "an individual or collective individuals."

Swanton's remarks also make worth consideration the possibility that it may have been the *čalakaθa* division of the Shawnee which De Soto encountered in western North Carolina in 1540. This supposition is admittedly based on slender evidence, but it receives some measure of support from Shawnee traditions, certain of which assign a definite southeastern origin for the *čalakaθa* division. The description of the people in the province of Chalaque would fit the Shawnee, who lived a part of the year in villages and raised small crops of corn but were essentially hunters and gatherers; however, the description is too general and might be attached with equal plausibility to too many other groups to be of any great aid.

1584.—In 1584 the chronicler for Raleigh's first colony mentions a "greate towne called Chawanock" northwest of Roanoke on the Chowan river in northeastern North Carolina. The location of Chawanock was, it might be noted, a scant 400 miles northeast of De Soto's province of Chalaque. In 1585 some of the men from Raleigh's second colony at Roanoke visited "Chawonock" and reported it as "the greatest province upon the [Chowan] river, and the town itself can put 700 men into the field, besides the forces of the rest [i.e., of the towns subject to Chawonock]. The King is lame, but hath more understanding than all the rest." In 1606 and 1608 Capt. John Smith and some of his colonists also visited Chawonock⁸ and in 1608 Smith writes, "Master Sicklemore well returned from Chawwonoke. . . . The river he saw was not great, the people few, the country most overgrown with pynes. . . . But by the river the ground was good and exceedingly fruitful." In 1621 Sir Frances Wyat, Governor, also "travelled to the South River Chawonock, some 60 miles overland from Jamestown, which he

⁷ 22, p. 204-205.

⁸ The same suffix is added to the names of two other Shawnee divisions, *pekowi* and *kispoko*, to denote "person(s) of *pekowi*," "person(s) of *kispoko*." I never heard it added to the names of the *mekose* or *šakiwila* divisions, however.

⁹ 18, p. 3.

¹⁰ 18, pp. 5-6.

¹¹ 18, pp. 25, 87.

¹² 18, p. 87.

found to be a very fruitful and pleasant country, yielding two harvests in a year . . . was kindly used by the people and so returned."¹¹

There seems little reason to doubt that the term *Chawanock* or its equivalent is used in the above reference to designate an Algonquian tribe or confederacy, the name for the group being taken from the main village settlement. In the brief sketch of the Chowanoc in the Handbook it is recorded that the tribe "gradually dwindled away before the whites, and in 1701 were reduced to a single village. . . . They joined in the Tuscarora war against the whites in 1711-12. . . . In 1820 they were supposed to be extinct."¹² Our entire information concerning the Chowanoc is limited to some twenty historical references. No mention is made to a part of the group moving from their seat on Chowan river; yet, when we consider the differences in population noted for the Chowanoc in 1585 and 1608, the withdrawal of a part of the tribe becomes an interesting possibility. As to the connection of the North Carolina Chowan with the Shawnee, we were until recently inclined to minimize the possibility of any such linkage, because the names of several Chowanoc villages bear no resemblance to any names one might expect for Shawnee villages, which were customarily designated by the same name as the division occupying them. However, in C. C. Trowbridge's manuscript account of the Shawnee (1824), the Shawnee Prophet states that the tribe formerly comprised six divisions, that the proper name for the sixth was Shawano, and that it was formerly a leading division of the Shawnee but had been extinct for some time. The Prophet supposed that the tribal name was derived from the name for this extinct but once powerful division.¹³ If this division had any connection with the now extinct Chowanoc, we have here a valuable link in the chain between various southern and northern groups of Shawnee. I have at this time no other evidence to offer on the question. Before discussing the next possibility, which is concerned with one of these dubious northerly groups, I should like to point out that the Chowanoc of North Carolina may be the tribe referred to in the Delaware record of the Walum Olum as departing to the south lands together with the Nentegos (Nanticoke).¹⁴ The withdrawal of the Nentegos and "Shaw-anis" is generally interpreted as having occurred before the Algonquians reached the eastern seashore; granting this interpretation to be correct, it is of interest to find, in the historic period, a group known by a term approximating *Shawanis* at no great distance south of the Maryland Nanticoke.

1614.—We now come to an extremely interesting problem—that of the possible identity of a group referred to on the Dutch Carte Figurative for 1614 as "Sauwanew", located on the east bank of the Delaware river near its mouth, in New Jersey.¹⁵ In 1634 De Laet mentions the "Sawanoos" as living in the vicinity of the Delaware river,¹⁶ and a few

¹¹ 18, p. 148.

¹² Mooney (11).

¹³ Trowbridge (21).

¹⁴ 8, p. 204, song V, line 10.

¹⁵ 14, vol. 1, pp. 11, 18, and maps.

¹⁶ 8, p. 82.

years later the "Sauwanoos" and "Sauwan" are mapped as being located west of the Delaware, between that river and the Susquehanna in eastern Pennsylvania." Mooney sees no reason for considering any of the above terms as applying to the Shawnee proper; he gives as evidence (1) that, in 1646, the Shawnee do not appear either in Ruttenber's or Evelin's lists of northern and southern New Jersey tribes, and (2) that the term *Sauwanoo* was used by the Dutch as a generic term for "southerners", in the same way that *Wappanoo* was used for easterners."

Mooney's interpretation of the New Jersey data is not convincing. The terms *Sauwanoo* and *Wappanoo*, or their equivalents, are not only used as generic terms by Algonquian groups but are also, as we have seen, applied to specific groups as well. We have noted the use of Chowanock for a specific North Carolina group, and at the present time the Shawnee themselves refer to the Delaware group now located near Anadarko, Oklahoma, as *wapana'ki* or "easterners", meaning by this term one specific Delaware division.

In regard to Mooney's other objection, the lack of mention of the Shawnee in New Jersey lists of 1646 is not surprising. By this date the Shawnee had, in all likelihood, moved considerably west or south of the New Jersey location. Troubles with the Dutch colonists, who attempted to settle on the lower Delaware river before the arrival of the Swedes in 1638, or with the Seneca and related groups who were beginning to obtain guns from the English and Dutch traders, may explain the removal; if the New Jersey-Eastern Pennsylvania Shawnee were a part of the North Carolina group, they may have removed directly southward to rejoin this group.

An additional bit of corroborative evidence for the presence of a Shawnee group in the north early in the 17th century is contained in the Narrative of Hendrick Aupaumut, an educated Mohican, writing in 1791. Aupaumut states, "The Shawannese, who we called Weshauwonnoow, are our [Mohican] younger brothers according to ancient covenant between our forefathers—for our ancestors, near 200 years ago rescued them from the mouth of many nations, as well as of the Five Nations who were ready to swallow my younger brother Shawany, for which kind deliverance they ever have felt themselves under the greatest obligation to obey our voice—and many nations had knowledge of this."¹¹ Whether Aupaumut's dating is reliable is open to question; that the Mohican befriended the Shawnee as he states is well authenticated,¹² and in 1694 some Shawnee joined the Mohican tribe.¹³

An indication that the French had been informed of the presence of a Shawnee group in the northeast is found in a remark in Ragueneau's relation for 1651-52, "Another [Father] set out [from Quebec] with five or six neophytes in little bark Canoes, to go to the shores of Acadia and, by that route, find an easier approach to the tribes called Eteche-

¹¹ 13, p. 170; 6, vol. 1, p. 119; 19, pp. 42-3, 46-7, maps.

¹² 12, p. 581.

¹³ 1, p. 77.

¹⁴ 17, pt. 6:277-8.

¹⁵ 12, p. 582.

mins [Malecite], Abnaquiois [Abnaki], Sokoquiois [Sokoki], Sourikois [Micmac], Chaouanaquiois [Shawnee] . . . and numerous other *savage* nations, which are sedentary, and have villages of a thousand or two thousand fighting men."²¹

Certain indirect evidence should also be considered. When part of the Shawnee moved north to the Susquehanna and Delaware river region at the close of the seventeenth century, they seated themselves in the same location that the Dutch maps for the early part of the century accord the Sawanoos.²² The aid rendered by some of the Shawnee to the Andaste (Susquehannocks or Conestoga of the Susquehanna river) against the Iroquois prior to 1672²³ also indicates a probable early intimacy between certain Shawnee groups and tribes of the Delaware-Susquehanna region.

1625-1670.—For the period 1625-1670 no records have come to light of actual encounters by white traders, explorers, or missionaries with any group the name for which we can, with some degree of plausibility, associate with the Shawnee. Hearsay reports for this period concerning various Shawnee groups are fairly numerous and often contain conflicting statements; an attempt to evaluate their reliability would necessitate extended discussion. One point emerges with increasing clarity as the period 1625-1670 draws toward a close; this is the fact that by 1660 Shawnee groups were carrying on what appears to have been a lively trade with the Spanish in Florida. Father Lalemant, in 1662, mentions Shawnee captives' accounts of trading with persons whom the French judged were Spaniards.²⁴ In 1671 Marquette also refers to Shawnee-Spanish trade.²⁵ In 1674 Henry Woodward, interpreter for the South Carolina colony, met two Savana Indians who "brought Spanish beads and other trade as presents makeing signes yt they had commerce wth white people like unto me, whom are not good."²⁶ Nine years later we have La Salle's statement that he has invited a Shawnee group to discontinue commerce with the Spaniards and establish residence on the Illinois river.²⁷

From this brief review of the early literature, we have found evidence indicating the possibility of the Shawnee having been located in western North Carolina, northeastern North Carolina, southern New Jersey, and eastern Pennsylvania, during early historic times. The totality of the evidence suggests a more easterly location for the Shawnee during the early period of white contact than has generally been assigned this tribe.

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²¹ 7, vol. 87, p. 261.

²² 16, p. 180.

²³ 2, vol. 1, p. 226; 15, p. 129; 4, vol. 8, p. 174; 5, p. 65.

²⁴ 7, vol. 47, p. 144.

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²⁶ 20, pp. 306-7.

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The Muskogean Indians

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The Southeast aboriginal culture area extends over southeastern United States from the Atlantic Ocean to eastern Texas and from the Gulf of Mexico north to the Ohio River.¹ In 1700 the English and French found the Muskogean Indians predominant in this great area and the leading tribal groups in our present states of Georgia, Alabama, Mississippi, northern Florida, and western Tennessee. One hundred sixty years earlier when De Soto made his famous march through the Southeast, he practically skirted the protohistoric boundaries of Muskogean territories. If, instead of turning to the Southwest after leaving the South Carolina mountains, De Soto had journeyed northwesterly on through to the Ohio River, then westward to the Mississippi and south along that river, much light might have been focused on the mystery still obscuring the prehistory of the Ohio River Valley. The objective of this paper is to suggest the probability that between De Soto's time (1540) and 1700 Muskogean-speaking tribes were in the Ohio Valley and were probably residents of southern Indiana.

Muskogean-speaking Indians, believed to have been a brachycephalic, hypsicephalic physical type people² and members of the Hoka-Siouan linguistic stock,³ entered the southeast area from the west long enough prior to the earliest Spanish contact (1513?) to have built permanent towns (many of them fortified) in the midst of fertile fields, producing a wide variety of agricultural products.

It is not known precisely when and from where they came, but their late traditions show that they journeyed from the "back-bone of the world," which have been interpreted to mean the Rocky Mountains. All of their early traditions, when a route was specified, indicated that they came east *via* the Red River Valley. There are also intimations that some few arrived from Mexico at a very late period.⁴

Archeologists have not reached that degree of knowledge essential to speak of Muskogean material cultures, but rather as yet, of cultures found in Muskogean territories. The Southeast area is predominantly Mississippi Pattern in its material culture manifestations. Some evidence of the presence of Woodland culture peoples, or at least of Woodland material culture influence, is found. Whether this represents pre-Muskogean groups or was intrusive is not known. Indeed, the material culture characteristics of the earliest arriving Muskogean are not known; but in the course of time they made great contributions to the high cultural attainments later characteristic of the Southeast, which

¹ Swanton, 1935, p. 373.

² Dixon, 1928.

³ Sapir, 1929, p. 139.

⁴ Adair, 1775, p. 195; Le Page Du Pratz, 1763, II, 112.

in many respects rivaled the great civilizations created in the Southwest area and in Mexico.

Archaeological research has not established an accurate estimate of Muskogean contributions to the Southeast material culture. Along with the basic need for more excavation, a principal contributing factor is that the northern boundaries of prehistoric Muskogean territories are not known. If it can be established that Muskogean, or probably to be more correct, proto-Muskogean groups were resident in the Ohio Valley and were responsible for some part of the Middle Mississippi Phase material culture found there, it will greatly aid the assignment of Muskogean traits known in the South.

An illustration of the coordination of tradition, language, and history on this subject is afforded in the case of the Alabama,⁵ a tribe which in historic days was second only to the Muskogee themselves among the upper Creeks. Creek tradition says that when the Muskogees were trying to catch up with the Alabamas during the journey to their later homes, they found themselves at one time on the banks of the Ohio near the Wabash River. The length of the time duration of this sojourn is not indicated. De Soto, during the month of April, 1541, left the Chickasaw and set out toward the Northwest and on into the present state of Arkansas for a province called Alibamo. The Alabama and their close allies, the Tuskegee and Koasati, spoke a language dialect which was much closer to the Choctaw-Chickasaw language than to the Creek. The inference is that in 1541 some Alabama bands were living in Arkansas northwest of the Chickasaws where they had been in contact with Chickasaw groups long enough to have acquired or to have continued to retain the latter's speech and that sometime after 1541 they had moved northeastward to the Ohio and from there southward to their historic seats. Sometime between 1541 and 1673 the Siouan Quapaw moved into the Arkansas territories, for there they were found by Marquette in the latter year and by La Salle in 1681.⁶

The historic territories of the Chickasaw were in western Tennessee and northern Mississippi. Traditional and historical sources indicate that some of their people were dwellers in the Ohio Valley, both in early and late times. Traditionally, the Chickasaw and Choctaw came from the West as one family. This early relationship is confirmed linguistically in the close similarity of the Chickasaw dialect to Choctaw. According to tradition, after wandering away from the Choctaw, some Chickasaw groups went to the North as far as the Ohio River where they stayed for a short time and then returned to their own people. Historically, they are known to have had a colony on the lower courses of the Tennessee River (i. e., in northwestern Kentucky), and "in comparatively late times a small body settled temporarily on the Ohio." The Chickasaw were in contact with dolichocranial groups to their north to the extent that brachycranial characteristics were in the course of time considerably altered.⁷

⁵ Swanton, 1922, pp. 191-93.

⁶ For a summary of this problem see Weer, 1937, p. 117.

⁷ Swanton, 1922, p. 419.

⁸ Swanton, 1928, No. 1, p. 677.

The word "Muskogee," from which was derived the linguistic family name, is not a Muskogean word at all; and no Creek knew its meaning. It probably came from the Algonkian tongue and meant "swamp" or "wet ground," first to be used by the Shawnee to identify a Creek tribe. The appellative "Creek" is of English origin, first used by South Carolinians to designate a tribe living on Oconee Creek, Georgia. The great Muskogean language family had no single name to distinguish as a unit the some fifty historic tribes.

As I have suggested on an earlier page, it is probably more correct to refer to prehistoric Muskogean groups believed to have been resident in the Ohio Valley as proto-Muskogean.

Swanton advanced the theory that the social and ceremonial practices of the Creeks alone⁹ were sufficient to have accounted for the great mounds of the Mississippi Valley and that the abandonment of the Ohio Valley mound area prior to white contact was evidently due to the shifting of Muskogean tribes to the South or the movement of Siouan groups southeastward and to the west or both. Bushnell, in 1934, also postulated these movements.¹⁰ Creek and Siouan traditions suggest the same. With physical and linguistic similarities as a suggestive basis future research may discover that the roots from which the Siouans developed grew in Muskogean soil and that historical differentiation between the Creeks and some of the Siouans materialized after they left the Ohio Valley. Prehistoric contacts here were of great importance and, as yet, are but little understood. Archeological investigations show conclusively that two basic material culture patterns, Mississippi and Woodland, met in the Ohio Valley and manifestations of their intermixture are found in southern and central Indiana.¹¹ The peoples who produced these two patterns must have had historical cultural traditions of diverse origins. Archeology has a suggestion to offer concerning the bearers of the Mississippi Pattern. Material culture similarities in what is technically described as the Middle Mississippi Phase of the Mississippi Pattern are found in Arkansas and in southern Indiana from the lower Wabash River as far northeast as Clark County. This proposes the probability that among those who left these manifestations in Indiana were Choctaw-speaking Muskogean Indians who in the shadowy period dividing prehistoric and protohistoric days found new homes in Georgia and Alabama, there to become historically known as members of the Muskogean Creek confederacy.

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⁹ Swanton, 1928, No. 2, p. 506.

¹⁰ Bushnell, 1934.

¹¹ Lilly, 1937, pp. 22-24; Black, 1934, pp. 192-94.

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Ofo-Biloxi Sound Correspondences

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John R. Swanton, who rediscovered spoken Ofo in 1908, when it was thought to have been extinct since 1784, found that he was able to record Ofo with somewhat fewer [phonemic] symbols than Dorsey had previously used for recording Biloxi; notably differing from Biloxi is the Ofo *-Ch-* sequence. "Probably the consonants followed by *h*, which is here very distinct, correspond to the aspirated consonants of other Siouan dialects."

On a close reading of the author's Bulletin 47, I find that he nowhere places the Ofo and Biloxi in a sub-group by themselves; indeed, in looking for the nearest relatives to these two languages, Swanton even mentions distant western kin of the Biloxi (p. 10), but for more intimate relationship the eastern Siouan tribes in general are indicated, which makes Biloxi and Ofo fall incidentally in one large eastern group rather than rest exclusively in a small southeastern group (p. 12). Later papers by the same authority ("New Light . . ." 1923, "Early History . . ." 1936) show more interest in the extreme divergency of Catawba than in placing Biloxi and Ofo more closely with themselves or with other Siouan dialects.

Two factors would naturally make one hesitate in ascribing Biloxi and Ofo to one genetically homogeneous group. A rapid survey of the two vocabularies shows that only a fraction of the words known are cognate—contrast this with the Hidatsa-Crow group, where a good sampling shows almost all words to be cognate. Secondly, the Ofo, alias Offagoula, alias Mosopelea, were supposed to be in the Ohio Valley in early times, going south to become neighbors of the Biloxi only after the 17th century.

As to the first factor, a large fraction of non-cognate words in Ofo and Biloxi suggests close, perhaps recent, cultural contacts with Muskogean speaking tribes; this can be demonstrated only after a large body of pan-Siouan and pan-Muskogean words are collected. As to the second factor, if comparative work can show Ofo-Biloxi to be a genetic sub-group of Siouan, historical evidence for early Siouan occupancy of the Ohio Valley will need to be interpreted as including both members of the group, with the Biloxi preceding the Ofo south rather than remaining in the south to be joined by the Ofo; comparative work for demonstrating a genetic sub-group must ultimately include all related languages, but a study limited to the two languages directly involved can provide a tentative hypothesis.

The correspondences which follow would seem to indicate that the Ofo and Biloxi at one time spoke a single language which changed in

¹1. p. 4.

both Ofo and Biloxi, but rather more in the latter; that is to say, Ofo appears to be the more archaic language of this group.

Examples are from the Dorsey-Swanton Bulletin 47; one example for each correspondence is cited, together with a parenthetic number indicating the total number of correspondences found. Only the more obvious cognates were counted by me.

1. *p* : *p*(15) and *ph* : *p*(12). Ofo *itce'pe*, Bil. *ayepi*, *aye'wi* 'door, window'; Ofo *aphe'ti*, *aphi'ti*, Bil. *pe'ti*, *peti'*, *pet* 'fire'.

2. *m* : *m*(8). In all examples except one, the Biloxi cognate lacks the initial vowel of the Ofo form; the remaining example reverses this relationship of initial vowel. Ofo *ama'*, Bil. *ma*, *mani* 'turkey'; Ofo *ma'hi*, Bil. *imakin'* 'to paddle'. Other labials (*w*, *b*) may perhaps be regarded as phonetic variants of the phonemes *p*, *ph*, *m*. Swanton says (Bull. 47, p. 2), Bil. "*b* occurs only once, in a proper name." The phonemic status of Ofo *b* is doubtful. According to the printed orthography, Ofo *b* corresponds to Bil. *w* twice (as does Ofo *m* and *p*), to Bil. *p* once.

3. *t* : *t*(17), *d*(16) and *th* : *t*(9), *d*(1). Ofo *to'pa*, Bil. *topa'* 'four'; Ofo *te*, *ti*, Bil. *de* 'to go'; Ofo *the*, *tse*, Bil. *ti*, *tedi* (with medial *t*) 'to die'; Ofo *atha'*, Bil. *adi* 'father'. Ofo *t* and *th* also correspond to Bil. *n*(3), *te*(2), *ts*(1), *xy*(1), *y*(1) possibly reflecting Biloxi phonology rather than regular correspondence (parallel to the development of Hidatsa *t* and *p* from *r* and *w* in final position, for example). The phonemic status of Ofo *d* is in question; correspondences with Bil. (3) are as for Ofo *t*.

4. *tc* : *tc*(12), *t*(3), *d*(2) and *tch* : *tc*(6), *t*(1). Ofo *ile'tci'*, *ile'tci*, Bil. *yetc'i'* 'tongue'; Ofo *itca(tho')pka*, Bil. *itapka* 'pestel'; Ofo *itco'ti*, Bil. *do'di* 'throat'; Ofo *tchi'pi*, Bil. *tc'wi'*, *tc'wiya'* 'intestines'; Ofo *itcho'hi*, Bil. *tohi*, *to'hü* 'green, unripe'.

5. *to* : *y*(11). Ofo *tea'maki*, Bil. *yamaki'* 'mosquito'.

6. *k* : *k*(22) and *kh* : *k*(5). Ofo *atce'ki*, Bil. *yek*, *ye'ki*, *ayeki* 'corn'; Ofo *akhu*, *ku*, Bil. *ku* 'to give'.

7. *l* : *n*(4), *d*(2), *y*(cp. 'tongue,' under 4, above). Ofo *le'yi*, Bil. *niye* 'to fly'; Ofo *li'tchi*, Bil. *ditei'* 'to dance'.

8. *n* : *n*(20). Ofo *ano'*, Bil. *anan'* '(north), winter'. An instance is found of *n* : *t* (but cp. the reverse, 3, above). In two cases a nasalized vowel in Ofo implies a nasal consonant in Biloxi (but all records of Siouan dialects are a little ambiguous in distinguishing between nasalized vowels and vowels juxtaposed to nasal consonants).

9. *y* : *n*(2), *y*(cp. 'to fly', 7, above). Ofo *iya'ti*, Bil. *na(ha)ti'*, *na(ha)di*, *na(ha)ti* (with medial *t*, *d*, and fortis *t*, apparently free alternates) 'canoe'.

10. *f* : *s*(9) and *fh* : *s*(9). Ofo *atcu'fi*, Bil. *yusi*, *ayusi'* 'ashes'; Ofo *fhi*, Bil. *si* 'yellow'.

11. *s* : *s*(5) and *sh* or *c* : *x*(9). Ofo *akon'si*, Bil. *kan'xi'* 'bee'; Ofo *amashu'-pka*, Bil. *maxon'-tka'* 'palmetto'. Is Ofo *sh* phonemically distinct from *c*? Cp. Ofo *aco'co*, Bil. *xoxo'* 'to cough'.

12. *h* : *h*(25). Cp. above under 2, 'to paddle', under 4, 'green'.

13. *i* : *i* not nasalized in either dialect (60; see examples above); nasalized in Bil. but not in Ofo (8); in Ofo but not in Bil. (1); in both

dialects (5). Ofo *i'fha*, Bil. *i^{nsu}*, *i^{nsu}'di* 'tooth'; Ofo *i^{nthe}*, Bil. *ite*, *te* 'forehead'; Ofo *iⁿ'tu*, Bil. *iⁿ'ti*, *indi*, *iⁿdiyaⁿ* 'egg'.

14. *i* : *e* (6). Ofo *oⁿ'yi*, Bil. *ane*, *anedi* 'louse'.

15. *i* : *a* (8). cp. 'door, window', 1, above.

16. *e* : *i* (7). Ofo *a'mife*, Bil. *misi* 'to sneeze'.

17. *e* : *e* (32). See examples above.

18. *a* : *a* not nasalized in either dialect (51; see examples above); nasalized in Ofo but not in Bil. (6; see 'turkey', 2, above, where a nasal consonant is found in the alternate form); nasalized in both dialects (5). Ofo *kifan*, Bil. *ksan*, *ksaⁿ'ni* 'five'.

19. *a* : *u* (3). Cp. 'tooth', 13, above.

20. *o* : *o* not nasalized in either dialect (13; see examples above). In general, when Ofo *o* is not nasalized, the Bil. correspondence is *o* (but cp. *o* : *aⁿ* in 'north, winter', 8, above); and conversely, when Ofo *o* is nasalized, the Bil. correspondences are *a* or *u* rather than *o*.

21. *oⁿ* : *aⁿ* (8; cp. 'bee', 11, above), *a* (4). Ofo *mon^{he}*, *i'to mon^{he}* 'to whoop (like Indians in old times)' possibly corresponding only to the Bil. forms in *m-*, if these are distinct from forms in *w-*, namely, *wahe*, *wahe'di* 'to cry out (as from pain)' and *mahedi* 'to halloo, whoop; to cry as the diving duck'.

22. *oⁿ* : *uⁿ* (3), *u* (3). Ofo *onⁿⁱ*, *oni*, Bil. *uⁿ'ni* 'mother'; Ofo *okhoⁿ'nki*, Bil. *okuki* 'to fish' (vowel-*n* is equated to nasalized vowel for practical intention; see 8, above).

23. *u* : *u* not nasalized in either dialect (8; see 'ashes', 10, above). In general, when both dialects show *u* nasalization is not recorded.

24. *u* : *o* (8; see 'palmetto', 11, above). When Ofo *u* corresponds to Bil. *o*, one or the other vowel is nasalized.

25. *u* : *i* (2; see 'egg', 13, above).

26. *V-* : zero-, and *-V* : -zero. Numerous instances show Ofo words beginning in *a-* and Bil. words, without initial vowel, beginning in consonants (e.g., 'turkey', 'palmetto', 2 and 11, above); with equal frequency, Ofo words in *i-* correspond to Bil. words in consonant without initial vowel (e.g., 'tongue', 'green, unripe', 4, above); also, Ofo words in final *-i* frequently correspond to Bil. words in final consonant, without final vowel: *an^{fhe}'pi*, Bil. *sep*, *a^{nse}'p*, *a^{nsepi}* 'ax'. This example shows what is possibly true for all initial and final vocalic loss, namely that the Bil. word appears to lack corresponding vowels only in certain forms. An instance where an Ofo word lacks initial vowel recorded for Bil. is also found (see 'paddle', 2, above).

Loss of original vowel between consonants, resulting in consonant clusters, is evident in both dialects; here again, however, vocalic loss in Bil. is general, in Ofo specialized.

27. CVC : CC(18), with Ofo *V* representing all vowels, most commonly *o* (5), *a* (5), *i* (4). Ofo *ashoⁿ'pi* 'to drink', Bil. *oxpa* 'to devour, eat up, drink up'; Ofo *oⁿ'fana*, Bil. *aⁿ'sna*, *aⁿ'suna* 'duck'; for *V* representing Ofo *i*, see 'five', 18, above.

28. CC : CVC(8). Ofo *phe*, Bil. *pehe*, *apehe* 'to pound'; Ofo *a'she*, Bil. *wehe* 'to sit'. The cluster, consonant-*h*, already noted by Swanton as an Ofo peculiarity, may represent in origin a CV*h* sequence, with *V* lost in syncope; -*Ch-* is then doubtless extended analogically.

29. CC : CC(22). Some instances where clusters (e.g., *-sk-*) are found in both dialects will reflect a Primitive Siouan cluster; other instances will reflect an old syncope when other dialects are brought into comparison with Biloxi and Ofo. And one may also expect that Bil. and Ofo preserve some vowels lost in other dialects; thus, CVC (sibilant-*e-p*) in both Bil. and Ofo ('ax', 26, above) corresponds to CC (*-θp-*) in Osage: (*moⁿ-hiⁿ-*)-*θpe* 'ax'.

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Relationships Among Various Clark County Sites

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The Ohio River forms the entire southern boundary of the State of Indiana. The archeological importance of this fact rests upon the evidence that the Ohio has served for centuries as a major artery for the migration and diffusion of various aboriginal peoples.

Although it is known that important aboriginal sites or landmarks appear about the mouth of every considerable stream entering the Ohio within this region, two principal occupational foci seem to stand apart from the rest as of special importance. One of these embraces an impressive area about the mouth of the Wabash River; the other comprises several square miles about, or near, Ohio Falls. As our investigations have extended, it has become increasingly apparent that the ethnology of these two locations is distinctly inter-related and that with each area there are evidences of marked changes in cultural characteristics occasioned by a contact or association of diverse peoples. At both locations the influence of such association upon pottery form and decoration is quite apparent.

Concerning the Ohio Falls location, it should be understood that, except at this point, there are no falls or rapids in the entire course of the Ohio. This is in itself important, especially when it is understood that from the earliest aboriginal times navigation about the Falls of the Ohio was of necessity accomplished by means of portages, one upon each side of the stream, both of which were within the actual precincts successively occupied by various Indian peoples.¹ What effect this situation may have had upon a prolonged and peaceful occupation of this eminently strategic location and to what degree such occupation may have affected migrations by alien peoples provide important elements in a critical archeological study of the region.

Nowhere in Indiana, or perhaps anywhere upon the Ohio, was there a more advantageous location for aboriginal occupancy. There was a remarkably abundant supply of fish-food and of the numerous species of edible molluscae, which persist to this day. Below the "falls" a glacial lake some 15 miles long was the habitat of great colonies of waterfowl. There were perhaps 100 smaller lakes existent a century ago. The extensive "knobland" forests abounded in deer, elk, bear, and other wild game. Beyond this the river terraces were here quite elevated and level, and the rich sandy loam was exceptionally fertile.

The fact is that various aboriginal peoples have successively occupied this immediate region, their villages overspreading more actual acres, perhaps, than is true of any other situation upon the Ohio. How many tons of animal bones have been left here—including those of mammals, fish, and fowl—no one may conceive. Numerous acres, within

¹ Gordon, Capt. Harry, 1916. Coll. Illinois Hist. Libr. 11:294.

which were the burials of hundreds of early peoples, have been washed into the Ohio during the past 100 years. During the extraordinary inundations of 1883-1884 local newspapers reported the complete destruction of these sites; yet during our recent excavation some 200 burials were encountered, and it is probable that many times this number still remain.

The geologic history of Ohio Falls is exceptionally complex, but it is indubitably an important or even paramount element in the local archeological picture. In order to evaluate this close relationship, one must remember, for example:

1. That the earliest occupants of the Ohio Falls sites were "lake dwellers" rather than simply the customary occupants of villages established upon stream terraces.

2. That during some phase or phases of the occupational sequence in this quarter the Ohio was in the process of establishing a new course, migrating meanwhile over an early lake-bed to its present location some three miles west of its earlier long-established channel.

3. That the present islands below the rapids were once integrated with the mainland and that upon them aboriginal peoples lived in villages not yet dissected from this mainland by stream piracy.

4. That for some centuries, or at least since the Ohio has occupied its present channel, periodic major inundations have wholly destroyed certain of the early villages in this area and that it was frequently necessary over a long period of time for the occupants of other sites to abandon their homes for brief or long periods.

During the building of the Louisville & Portland canal (*circa* 1830) aboriginal "fire hearths," skeletal remains, and artifacts were reported found at depths 20 to 30 feet below surface on the Kentucky side of the Ohio. No valid reason appears to discredit these reports. An examination of the artifacts recovered reveals that they pertain to the "Indian Knoll" culture-group, as described by Moore.¹ That the occupants of these sites later resorted to the higher terraces upon the Indiana shore one may assume, but this is not after all important. What is important is, as Dr. Butts has pointed out, that it is not probable that any of the spectacular changes in the Ohio mentioned must be referred to remote geological times.² It is certain, however, that these varied and often puzzling geologic involvements must be carefully weighed and considered in any competent analysis of the archeology of the region.

The general archeological sequence at Ohio Falls, as we now interpret it, is as follows:

1. A late or historic occupation during pioneer and pre-pioneer times by small transient groups, some of which may be identified as Shawnee and Delaware; probably, also, transitory occupations by the Cherokee at a somewhat earlier period. It is known that the Cherokee claimed the whole of Kentucky as their tribal habitat, and there are

¹ Moore, Clarence B., 1916. Some aboriginal sites on Green River, Kentucky. *Philadelphia Acad. Nat. Sci.*

² Butts, Charles, 1918. Reverse of topographic map of Camp Taylor and vicinity. U. S. Geol. Surv.

sparse records of Cherokee camps about Ohio Falls. In respect to the Shawnee and Delaware occupations the evidence is substantial and is a matter of fully authenticated record. So much may not be said of the probable Cherokee occupation of which the accounts are meager and less substantial.

Although Borden assumed that burials at Ohio Falls were "within stone graves and usually in a sitting posture," and Webb and Funkhouser² (probably upon these grounds) assumed also that this was true, we did not encounter during two seasons of excavation a single stone grave. It is true, however, that two or three stone graves are observable on surface within the lawn of the James Newcomb home (Newcomb site). No others have been observed or reported at Ohio Falls.

2. An intensive occupation, not however prolonged, by an integrated body of Middle-Mississippi peoples who, as we believe, were somewhat earlier established at Wickliffe, Kentucky; at the mouth of the Wabash; in Vanderburgh County, Indiana; and in Floyd County, Indiana, a few miles below Ohio Falls. This is the same group, we assume, who established themselves more unitedly at the Prather-Koons-Wiley sites in Utica Township, Clark County, some six or eight miles north from Ohio Falls. This concentration perhaps represents the easternmost outpost upon the Ohio of the group in question. These people built impressive mounds above the ruins of rectangular structures earlier destroyed by fire, buried their dead usually in an extended position, but sometimes with bodies flexed, beneath the village floor-level, or actually beneath the clay floors of their homes, used copper liberally and artistically, were adept in the fabrication of axes, celts, pipes, etc., of stone, and produced pottery of decorative character—this often including effigy forms.

It should be understood that at Ohio Falls every available acre has been cultivated for 150 years, that recurrent inundations have removed much of the surface soil so disturbed, that erosion has greatly altered the entire surface, that tons of boulders and other workshop material have been removed to facilitate cultivation or to be utilized for cement construction, and that for a great many years relic collectors have resorted to this area and have combed it consistently. It has been therefore impossible to determine the actual areal extent of this occupation or to estimate its importance.

3. An intensive occupation of relatively long duration by a numerous group of Middle-Mississippi peoples. In physical character and in their material culture, they are unlike Group 2; yet there are certain trait-similarities which suggest a contact between the two peoples. In this group the cranium is small and customarily occipitally flattened. Undeformed crania, so far as studied, are moderately dolichocephalic. This is opposed to Group 2, whose crania are relatively large, undeformed, and brachycephalic.

We have found within the midden deposits characteristic of this group no fragment of copper. The burials are customarily upon the

¹ Borden, Wm. W., 1874. Indiana Geol. Surv. 5:185-186.

² Webb, W. S. and Funkhouser, W. D., 1928. Ancient life in Kentucky. Kentucky Geol. Surv., p. 174.

right side and are rather acutely flexed. This flexation has been sometimes insured through the introduction of post-like slabs of limestone placed at knees, hips, feet, etc. As a burial practice, round or ovate boulders, always carefully chosen, were deposited in the graves. Red ocher and charcoal appear sparingly with most burials. Most unusual, we believe, is the characteristic use of pillow-like head-supports of native slate—these sometimes worked into roughly oval form but more often representing squared or rectangular quarry-slabs. The inclusion of funerary pottery is typical, and a specific form of pot has been used. This is of one-half gallon capacity, the body is ovoid and thin-walled, the rim is slightly flared, and the two handles are looped and rivetted. This funerary vessel is shell-tempered, as are practically all of the thousands of sherds recovered. It is plain or polished, as is most of the pottery in general. Perhaps one-fifth of the utilitarian vessels were cord-marked. The size range of these is from small and delicate forms to those of exceptional size. Truncate pans and straight-sided vessels are numerous, as are the "water bottle" forms. In vessels with handles both the loop and strap handle appears, but we have not observed the lugged form anywhere within this region.

Within the abundant midden deposits there were no grooved axes and no celts actually identifiable as such. Pestles with expanded bases were numerous, as were more or less crudely shaped mortars. Digging or agricultural tools were customarily of native slate and were quite often notched. Projectile points, knives, and drills were preponderately of the Wyandotte hornstone, so generally used by Ohio River peoples. The small flint scraper so typical of Wabash River sites does not appear at Ohio Falls or indeed anywhere in this region. While triangular points were perhaps most numerous, notched and stemmed types are almost equally so.

Even though "grave goods" are in this manifestation rare, crude bone drills, needles, etc., are sometimes present, as are tubular beads of bone, and discoidal beads of shell. Except in the decoration of elbow pipes, upon the bowls of which human effigy faces or heads appear, there is little attempt at decorative expression. Although pipes of stone or clay in elbow, ovoid, and conical forms are abundant and are included with burials, decoration seems confined to the elbow type.

4. An occupation of especial importance, involving an extensive area upon both sides of the Ohio, of a group whom Moore has described from the Indian Knoll site upon Green River, Kentucky, some 150 miles southwest of Ohio Falls.

The material culture of this group has been so well described by Moore that we shall attempt here only a few observations by way of comparison. It must be concluded that the concentration of these peoples at Ohio Falls was much more extensive and prolonged than that at Indian Knoll and that it comprised, in fact, a tribal center of this group. There is much reason to believe, also, that it was occupied much earlier.

In general, the cultural character of the two sites is identical. There are, however, suggestive differences. Among these are:

a. That while Moore found numerous objects of copper at Indian

Knoll, we found none whatsoever at Ohio Falls, either within the midden deposits attributable to these people or in those of Group 3 above them.

b. That while Moore reports that the flint implements of Indian Knoll were customarily of a "dark flint," which we suspect was derived from the prolific quarries of southern Indiana, it was observed at Ohio Falls that the group of Indian Knoll affinity had apparently no knowledge of this material, or in any event, used it insignificantly. It is because of this fact that we are inclined to believe that a certain chronological value attached to the use or disuse of this material by Indian peoples upon the Ohio.

In almost every respect the material culture displayed at Ohio Falls was superior to that of Indian Knoll. It was obviously slightly affected, if at all, by contact with other peoples. Neither at Ohio Falls or at Indian Knoll does it appear that pottery was made or tobacco used. At Ohio Falls, at least, it is apparent that the use of the bow-and-arrow, if it was used at all, was much less practiced than the use of the spear or lance.

Inasmuch as Hrdlicka has assumed upon the basis of cranial characteristics that the people of Indian Knoll were Algonquin, none of the crania collected at Ohio Falls have been studied. Although there are numerous points in Hrdlicka's analysis upon which one may not agree, we are inclined to be receptive in respect to a possible Algonquin affinity. Our reasons are based upon abundant similarities in culture-traits, however, and not upon the physical element.

5. A possible "pre-Indian Knoll" occupation characterized by extensive underlying, midden deposits usually displaying a sod-line "break" or contact between the inferior and superior midden accumulations. The homogeneous and richly organic deposits of this stratum are, in fact, quite different in character from those of the identified Indian Knoll levels. They are composed almost entirely of millions of small molluscae (Pleurocera, Campeloma, etc.) in varying stages of disintegration; this is opposed to midden deposits of the superior strata, in which the Unio prevails. There are within this stratum no bones of larger mammals, except such as may have accrued from the midden deposits above. Instead, the animal remains comprise those of fish and waterfowl. Though our excavations have revealed that this deposit extends to a maximum depth of 8 feet 9 inches, resting sometimes upon sterile glacial outwash clays and in other quarters upon the lacustrine clay of the earlier lake-bed, the whole of human origin, we have found nowhere human remains or artifacts within it.

It is admitted that we have heretofore assumed that this midden was attributable to an occupation by the group of Indian Knoll affinity, this assumption based upon the unreliability of "sod lines" in sites of this character and upon the fact that the Indian Knoll midden upon the Kentucky side was upon the same glacial clays, or marls, earlier mentioned.

Upon the now denuded islands below Ohio Falls and upon the low rock shelves slightly above the normal pool-stage of the Ohio, Folsomoid projectile points have been found frequently. Almost invariably these are patinated and reworked. Upon an extensive low terrace upon a

branch of Silver Creek in Monroe and Union townships, similar Folsomoids have been found at several unimpressive campsites, these barren of pottery, so far as we have observed. It is of course possible that the Folsomoids of Ohio Falls may have derived from the stratum we have just described, for certainly none have appeared in the upper strata.

At the Robinson site in Washington Township, there is an impressive circular earthwork. Near this are a number of unexplored stone graves, these quite obviously representing an intrusive occupation of the site by later peoples. At the so-called "stone fort" at the mouth of Fourteen Mile Creek, a difficult examination of the surface has revealed no other evidence than a few plain or cordmarked, shell-tempered sherds and a customary use of Wyandotte flint. Artifacts from an apparently related village site suggest a Middle-Mississippi association. Upon the site itself triangular arrow points appear most numerous.

In the foregoing we have attempted to discuss as briefly as possible the several complications presented in the region. It must be admitted that the entire Ohio Falls region is decidedly important archeologically. It must appear obvious that our own survey has accomplished little more than to suggest the desirability of further investigation.

SECTION ON BACTERIOLOGY

Chairman: P. A. TETRAULT, Purdue University

Good interest was maintained throughout the session of the section on Bacteriology. About 25 or 30 members were present during the greater part of the session. Since the program was short, no time limit was placed on discussion. The paper on *Streptococcus algalactiae* and that on immunization against rabies were discussed in considerable detail. A. R. Jamieson, of the Lilly Research Laboratories, was elected chairman of the section for the coming year.

ABSTRACTS

Disinfection. P. A. TETRAULT, Purdue University.—A general review of the action of disinfectants from bacteriological and chemical standpoint is presented. The influence on the rate of disinfection of such factors as change in concentration, temperature, pH, chemical constitution of disinfectant, and presence of organic matter is outlined.

Immunization against rabies using vaccines containing various amounts of protein. C. A. BEHRENS, L. B. SCHWEIGER, and J. L. REEVES, Purdue University.—All vaccines employed in prophylaxis against hydrophobia contain the virus of rabies and also a great deal of foreign material, practically all of them being suspensions of the infected nervous tissue of rabbits. Much of this undesirable foreign substance can be removed by precipitating it at its iso-electric point. These experiments employed vaccines with varying amounts up to about 60% of this inert material removed. The vaccines were prepared by adding homogeneous rabic brain emulsions to 0.2, 0.4, 0.5, 0.6, 0.8, 1.0, and 1.1 mls. of 1/100 molar citric acid, this procedure removing 15, 24, 30, 34, 43, 58, 62% of the protein. Their minimum lethal doses are 0.5 ml. injected intracranially of dilutions of 1 to 14000, 12000, 12000, 12000, 50000, 3000, and 2000, respectively. When 0.5 ml. of a rabic brain emulsion is similarly injected in rabbits, a dilution of 1:25000 is fatal; a dilution of 1:26000 is non-infective. Rabbits were immunized by injecting 2 or 10 mls. daily for 10 days and, consequently, received 20 or 100 mls. of these vaccines, subcutaneously or intravenously. Ten or 28 days after their last vaccine treatment they were tested to ascertain their degree of resistance by injecting intracranially 0.5 ml. of a 1:20000 dilution of rabic emulsion. All vaccinated rabbits, irrespective of the amount, the type, or the method of administration of the vaccine, were able to withstand two minimum lethal doses 10 or 28 days after receiving their last vaccination. Rabbits inoculated intravenously with 2 ml. doses, receiving 20 mls. of the vaccine, seemed to possess greater resistance against 3 minimum lethal doses than those injected subcutaneously when tested 28 days after their last vaccine treatment. Fifty per cent of the rabbits injected daily subcutaneously or intravenously with 10 ml. doses, receiving 100 mls. of the vaccine and tested against

3 minimum lethal doses 10 or 28 days after vaccination, are immune to rabies. None of the immunized rabbits withstood 4 minimum lethal doses.

Factors influencing the growth of *Oospora lactis* in cream. E. H. PARFITT, Purdue University.—When cream is held under farm conditions, the factors influencing the growth of *Oospora lactis* are found to be the time and temperature, the amount of cream surface area exposed to the air, the degree of agitation of cream during storage, the method of adding fresh cream to the accumulated supply, and the milk-fat content of the cream. Molds in cream are of interest in that a knowledge of their population may be used as an index of the state of decomposition of the cream.

Biophysical study of *Oospora lactis*. E. H. PARFITT, Purdue University.—From sour cream and butter were isolated what appear to be eight different varieties of *Oospora lactis*, which were found to differ in macroscopic and microscopic appearance, ability to hydrolyse milk fat, production of spores and mycelia when grown in substrates of different pH levels, ability to produce an odor, thermal death points, and optimum growth temperatures.

The detection of chlorine-resistant bacteria in a swimming pool. G. H. ECHELBERGER, Purdue University.—This paper reports the number of organisms present in a chlorinated swimming pool and the effect of certain physical and chemical factors upon holding samples.

The application of the phosphatase test to butter. W. H. BROWN, Purdue University.—The phosphatase test as it is used for milk has been applied to butter to determine whether or not the cream has been properly pasteurized prior to churning. The Scharer technique has been followed, with 1 ml. of butter serum used to replace the 1 ml. of milk. The butter serum is collected by centrifuging the sample of melted butter. The test shows that some samples of the commercial butter react phosphatase-positive. A large percentage of the samples that gave a positive phosphatase test, when subjected to the keeping-quality test of 15.4° C. for 10 days, dropped in score more than did those that gave a negative phosphatase test. The method used to pasteurize the cream has been found to influence the number of samples reacting to the test, and the test points out that pasteurization is an individual plant problem.

Milking machines a source of thermoduric bacteria. E. H. PARFITT, Purdue University.—In one of the large middle western cities where difficulty was found in maintaining a satisfactory bacterial count in adequately pasteurized milk, investigation showed that the incoming milk from certain territories was heavily inoculated with thermoduric bacteria, and these thermoduric bacteria were associated with insufficient care of milking machines. The organism isolated was a gram-positive micrococcus, which, when growing on nutrient agar, produced in from four to six days a yellow pigment, did not reduce methylene blue or litmus, and had a majority thermal death point between 65 and 67° C. when held for 30 minutes of time.

The Rapid Identification of *Streptococcus agalactiae*

ALFRED H. BRUECKNER and STANLEY E. HARTSELL, Purdue University

The typing of streptococci by serological methods, particularly the precipitin technique of Lancefield (1928) has been shown to be reliable not only for the identification of cultures but also for the demonstration of the various antigenic constituents of their cells. To those interested in the rapid detection of streptococci the problem of making this technique available to dairy and health laboratories is receiving considerable attention at this time.

It is obvious that such a method would be of great assistance to these institutions; however, one feature of precipitin techniques is that the preparation of large numbers of extractives from the cultures and the necessary centrifugation of the cells is time-consuming. These factors may be a limitation in some laboratories doing routine bacteriological work with milk, and any test which could obviate these difficulties would be greatly appreciated.

It appears that a rapid, inexpensive, and reliable method for the determination of Group B streptococci by the agglutination method could be used to good advantage in reducing the number of cultures which would require the precipitin technique before their group would be known. However, we observe frequently that any attempt to utilize agglutination methods with cultures of streptococci has had little success because of the tendency of these forms to agglutinate spontaneously. Griffith (1926) devised a method with which he could classify *Streptococcus pyogenes* by the use of a rapid slide agglutination test. Later Stableforth (1932) utilized a similar technique for the identification of *Streptococcus agalactiae*. In a recent report Stableforth (1938) records the extensive use of this test in typing many strains of this microorganism. Even the identification of sub-types within Group B streptococci was accomplished with relative ease. Some cultures were spontaneously agglutinable or inagglutinable, and further tests were required before their serological type could be known. Plastridge and Hartsell (1937), in their work on the biochemical and serological reaction of *Streptococcus agalactiae*, discarded this method because of these difficulties.

The present report describes the development of a microscopic slide agglutination technique for the rapid detection of *Streptococcus agalactiae* after its isolation from routine milk samples. Spontaneous agglutination among cultures has been greatly reduced, and by the use of this test *Streptococcus agalactiae* can be identified in 72 hours after the milk sample has been taken. No biochemical or involved serological tests are required to type most of the strains of this organism. An attempt to adapt the Neufeld technique to the identification of *Streptococcus agalactiae* will also be discussed.

Preliminary Experiments

In studying the biochemical and serological relationship of *Streptococcus agalactiae* (1937), the encapsulation of some cultures was noted on primary isolation. Stained smears made from the incubated milk tubes showed well marked capsules; however, these structures were seen so infrequently that they were regarded as artifacts. It seemed appropriate to reinvestigate this problem with a view to adapting the Neufeld technique for the typing of pneumococci to the identification of *Streptococcus agalactiae*. Such an adaption, if successful, would obviate the necessity of using blood agar plates and subsequent biochemical and serological determinations of the pure culture for the detection of this species in milk.

Cultures.—Twenty-four cultures of streptococci, regarded as members of Lancefield's Group B, were received from Dr. W. N. Plastridge. These strains included the well known cultures "090 T" and "V9" of Lancefield, as well as strain PH 281, which was isolated originally by Mr. Mickle. The first two of these strains have been studied extensively by many investigators, the most recent report concerning their encapsulation being that of Dawson (1938).

Antibacterial serums.—Antiserums were prepared by injecting rabbits intravenously with a 0.5% suspension of packed formalized cells in saline solution. These antigens contained the growth from cultures cultivated in a proteose-peptone, phosphate beef-infusion medium for 48 hours. The rabbits were injected according to the method of Foote, Welch, West, and Borman (1936), which had been shown to be suitable for the production of satisfactory Group B antiserum (1937).

Capsule stimulation.—Since most of the pure cultures did not show a well-defined capsule, the first problem was that of inducing the development of this structure before the Neufeld technique could be applied. Daily transfers of the 24 strains were carried out in a blood-milk broth with a beef-infusion base. Examinations for capsules by the method of Howie and Kirkpatrick (1934) after three transfers showed slight capsule formation in 13 of the 24 strains. It was observed that capsular development under these conditions was variable and that large capsules were never found.

Negative results were also obtained by using blood-milk agar slants (5% cow blood, 5% milk in beef infusion agar) and a skimmed milk medium even when daily transfers were continued for ten days. Passage of the cultures through mice failed to stimulate a definite increase in capsular material. In the presence of homologous serum, 090 T and all other strains failed to show capsule swelling.

In view of the work of Jennings (1931) with human streptococci, the methods of bacterial variation were employed to encourage capsule formation. He showed that unencapsulated streptococci might become capsulated and grow as mucoid colonies on blood agar after many transfers in blood media. Dawson (1938) has recently reviewed the litera-

ture on this subject and records the development of the mucoid phase and capsules for strain 090 T.

It was thought that an encapsulated strain of *Streptococcus agalactiae* (possibly strain 090 T) might be used with the serum of cows to detect mastitis. Then it would be possible to eliminate the use of any cultural methods for the detection of infection due to this species. The presence of antibodies in the serum of the infected cow would constitute a positive diagnosis. With this viewpoint in mind strains 090 T, V9, and PH 281 were grown in blood broth and transferred daily for six days. On the seventh day blood agar plates were streaked and then incubated for 24 hours at 37° C. A small inoculum from the edge of the colony was transferred again to blood broth. This procedure was carried through six series without a mucoid phase being observed in any of the plates. This part of the work is being extended.

Observation of capsule swelling.—Whenever even slightly encapsulated organisms were noted in the above experiments, they were subjected to exposure to homologous serum in a hanging drop and observed for capsule swelling. The first hanging drops were examined immediately as in the Neufeld technic. Then incubation of the serum-antigen mixtures was tried at 37° C. for one hour. Even when these preparations were held at this temperature for 24 hours in a humid atmosphere (water bath), no capsule swelling was seen. In these experiments we noted that many of the serums caused a consistent and definite agglutination of their antigen; and in view of the many unsuccessful attempts to produce the swelling, a further study of this agglutination was considered expedient.

The Microscopic Agglutination Test

The same serums used in the work just reported were employed in a reinvestigation of the microscopic agglutination test. It was first demonstrated that serums for strains 090 T, V9, and PH 281 had a precipitin titre of 1-100 and that only a slight reaction was observed in cross-precipitin tests. The precipitation with the homologous serum was sufficiently strong so that there was no question as to type relationships. Cross-agglutination tests also supported these correlations. In the identification of *Streptococcus agalactiae* on primary isolation the three antisera for Lancefield's types I (Strain 090 T), II (Strain V9), and III (Strain PH 281) were employed.

Strains to be used as antigens were grown in beef-infusion proteose-peptone broth containing approximately 5% defibrinated cow blood. One loopful of the broth culture which had been incubated at 37° C. for 12-18 hours was removed from the upper half of the medium and placed on a clean cover slip. Every effort was made to keep from agitating the culture, since very few calls were needed in the hanging drop; and large granular clumps of cells which occur frequently on the sides of the tube would confuse the detection of agglutination. One loopful of undiluted antiserum was then added to the drop of culture. The addition of enough alkaline methylene blue to this mixture to color it lightly facilitates reading the tests but does not alter the reaction. The coverslip was

mounted in the usual way and the preparation incubated over water at 45-50° C. in a water bath. Readings were made by microscopic examination of the hanging drop with the high dry lens. Final readings were made after four hours' incubation, although most positive tests were detected in two hours. A control, containing only a loopful of the broth culture, was made for each organism so that spontaneous clumping, if it occurred, would be detected. Positive tests showed definite clumping of the organisms as contrasted to the free chains of cells in the control. An arbitrary system of recording the extent of agglutination was adopted: 3+, approximately 90% of the cells in the hanging drop were in aggregates; 2+, about 50% were in clumps; 1+, from 10 to 20% of the cells showed agglutination. Occasionally, clumping reached a macroscopic state (4+) in strongly positive tests, and the clumps could be seen in the drop with the unaided eye.

Experimental

If the microscopic agglutination test is to be of any value in the routine examination of milk samples, it should require a minimum of time and materials and still give reliable results. With this viewpoint in mind, 261 quarter-samples of 59 cows were taken in two different herds and the 75 isolations of streptococci examined by the above technique.

Procedure with isolated strains.—The method of Plastringer and his associates (1934) was used in collecting the milk samples aseptically. They were incubated over night at 37° C. and then examined culturally. One loopful of each incubated sample was streaked on one quarter of a cow-blood agar plate and then incubated for 24 hours at 37° C. Breed smears were also made and examined for the presence of streptococci and for leucocytes in the incubated milk. All weakly hemolytic colonies were picked from the plates and transferred to beef infusion blood broth. In a few cases short chain streptococci were seen in the microscopic examination, but no hemolytic colonies were found on the original or repeated platings. These cultures proved to be micrococci or streptococci, giving biochemical reactions typical of *Streptococcus lactis*. All isolations in the present investigation which gave typical *Streptococcus agalactiae* biochemical reactions were weakly hemolytic. The broth cultures obtained from the blood agar plate colonies were used as antigens in the microscopic agglutination test. Each isolation was tested with anti-serums prepared against organisms representing the three types of Lancefield's Group B Streptococci. Biochemical studies of all isolations were made according to the method of Plastringer (1934).

Results

Preliminary isolation experiments were done with a local dairy herd which was at that time having trouble with mastitis. Encouraging results were obtained with the microscopic slide agglutination tests, and a more comprehensive survey of a larger herd was undertaken to determine the efficiency of the test. Table I shows the biochemical and serological reactions of certain isolated strains.

TABLE I.—Identification of Selected Isolated Strains of *Streptococcus agalactiae*

Culture Cow Number	Source Quarter	Biochemical Reactions									Microscopic Slide Test Type Serums			Control
		Hemolysis	L.M.	M.B.	L.	Mn.	I.	Raf.	Ssl.	Ar.	I (090 T)	II (V9)	III (PH 281)	
302	L.F.	beta	ACpR	0	A	0	0	0	A	0	0	2+	3+	—
295	R.R.	beta	ACpR	0	A	0	0	0	A	0	3+	3+	2+	—
299	L.R.	beta	ACpR	0	A	0	0	0	Sl.A	0	2+	2+	3+	—
290	L.F.	beta	ACpR	0	A	0	0	0	A	0	2+	2+	+	—
521	L.R.	beta	ACpR	0	A	0	0	0	A	0	+	3+	3+	—
306	L.F.	beta	ACpR	0	A	0	0	0	A	0	3+	3+	3+	—

Abbreviations: L.F.=left front quarter; L.R.=left rear quarter; R.R.=right rear quarter.

Biochemical Reactions: in Litmus milk, ACpR=acid, coagulation and partial reduction. L.=Lactose; Mn.=Mannite; I.=Inulin; Raf.=Raffinose; Sal.=salicin; Ar.=Arabinose.

Reactions in Methylene Blue Milk: 0=no reduction.

Fermentation Reactions: A=acid; 0=no acid.

Serological Reactions: 0=no agglutination; +=approximately 20% of cells agglutinated; 2+=approximately 50% of cells agglutinated; 3+=approximately 90% of cells agglutinated.

It will be noted that there is a remarkable agreement between the biochemical and serological properties of these strains. Seventy of the 75 isolations made in the present investigation gave cultural and biochemical tests which identified them definitely as *Streptococcus agalactiae*. As stated previously, only the reactions of representative isolations were included in the table. The other five strains gave reactions which were atypical of *Streptococcus agalactiae*, notably the complete reduction of methylene blue and litmus milk. These five cultures gave negative serological reactions, except for one, which gave a slight reaction with 090 T antiserum.

Of the 70 strains classified as *Streptococcus agalactiae*, 69 or 98.5% were detectable by the microscopic agglutination test, the one exceptional strain being spontaneously agglutinable to the point where clear-cut readings could not be made. Forty-four of the 70 *Streptococcus agalactiae* strains were isolated from different quarters, and 26 were obtained in repeat tests on the same quarters. Since the strains isolated on the second sampling of a given quarter often gave strong evidence of being the same as those isolated in the original sampling, especially in the intensity of the agglutination reaction; it is of interest to survey the data from this standpoint. In Table II we note that practically all strains, when isolated from the first milk sample of a quarter, can be designated easily as *Streptococcus agalactiae*. Only one of the 44 strains could not be typed. This indicated definitely that the test was

TABLE II.—Degree of Reaction of Isolated Strains Against All the Test Serums

Degree of Reactions*	Original and Repeat Isolations		Original Isolations Only	
	No. of Strains	% of Total Strains	No. of Strains	% of Total Strains
Strongly Positive.....	37	52.9	29	65.9
Positive.....	24	34.3	13	29.5
Weakly Positive.....	8	11.4	1	2.3
Spontaneous.....	1	1.4	1	2.3
Total.....	70	100.0	44	100.0

*The arbitrary standards for degree of reaction:

Strongly Positive = 3+ or 4+ reaction with at least one of the three test sera.

Positive = 2+ reaction with at least one serum and some reaction with two sera.

Weakly Positive = 1+ reaction only with any serum.

Spontaneous = cells agglutinated even in absence of any sera.

of value when a rapid determination for Group B streptococci was desired.

The question arises as to whether the three test serums employed in our investigation need be used when testing routinely for *Streptococcus agalactiae* or Group B streptococci in general. In this connection it should be remembered that, while the serums were not wholly type specific, they reacted much more strongly toward homologous than toward heterologous organisms. A survey of the weak and negative reactions of the 44 strains of *Streptococcus agalactiae* isolated from different quarters (Table III) shows that in our work it was advisable to use the three test sera.

Stableforth (1938) has shown that there is rather a close correlation between the infecting types of *Streptococcus agalactiae* in the different quarters of a cow and the prevalence of these types in the herd. The spread of the organism from one quarter to another quarter in the same cow has been shown by agglutination methods to be brought about by the

TABLE III.—The Number of Strains Giving Negative or Weak Reactions with Each Test Serum

Antiserum Prepared Against Strain:	Negative No.	Strains %	*± and + strains		Total % and Weak
			No.	%	
090 T	2	4.6	8	18.6	23.2
V9	1	2.3	4	9.3	11.6
PH 281	2	4.6	7	16.3	20.9

*4 strains weak with both 090 T and PH 281; 1 strain weak with both 090 T and V9.

same serological types. Some evidence to support Stableforth's observation was noted in the use of the microscopic agglutination test. Because of cross reactions found in the preliminary titrations, little was expected in the way of typing organisms. However, it was soon obvious that the isolated strains did show differences in their reactions toward the three sera, and typing of a sort was taking place.

The strains of *Streptococcus agalactiae* from the different quarters of 7 of 13 cows gave identical agglutination reactions. Five of the 13 cattle were re-tested a second time, and the data indicated that the infecting types did not change during the interval (three months) between tests. It is realized that the above data are too few to support all the facts on the spread of mastitis infection; however, the possibilities of the microscopic agglutination test in such a study is indicated clearly.

Agglutination tests were also made with all sera against the following species of streptococci: *Streptococcus lactis* (5 strains), *Streptococcus bovis* (4 strains), *Streptococcus citrovorus* (1 strain), *Streptococcus scarlatinae* (1 strain), *Streptococcus epidemicus* (1 strain), *Streptococcus fecalis* (2 strains). We are indebted to J. M. Sherman, Alice Evans, and B. W. Hammer for subcultures of these species. One strain of *Streptococcus bovis* (No. 113) gave a slight reaction in the presence of V9 antiserum. Three strains of *Streptococcus lactis* and one strain of *Streptococcus fecalis* reacted spontaneously; otherwise, all other agglutination tests were negative.

Discussion

From our results it is evident that the microscopic agglutination test can be used successfully in the identification of *Streptococcus agalactiae*. The difficulties of spontaneous agglutination have been to a large extent minimized by the use of young serum-broth cultures as antigens. Apparently, the serum present in the blood broth sensitizes the cells to the action of the agglutinins, thus reducing the probability of agglutination due to the electrolyte in the absence of specific antiserum. Since cow blood was used in preparing the broth media in this investigation, the possible influence of antibodies in the blood from a mastitis-infected cow was considered. We used the blood from cows shedding *Streptococcus agalactiae* and from other animals which were free from this infection. No difference was discernable in intensity of the agglutination reaction or in the type specificity of the streptococci when blood from these sources was employed in the preparation of media.

The use of a small amount of the broth culture, which is free from clumps of cells often observed in cultures of streptococci, may also minimize the probability of spontaneous agglutination. The necessity of resuspending the cells in a solution containing an electrolyte has been obviated and may account, in part, for the detection of 98% of the cultures without this limitation. The centrifugation of broth cultures has been eliminated in the slide agglutination test. Concentrated cell suspensions are not only unnecessary but even detrimental in the microscopic agglutination test.

It is of interest to compare the microscopic agglutination test and

the rapid macroscopic agglutination test of Stableforth (1932). In the latter method "suspected colonies are picked into 30 cc. of serum broth, each streptococcal growth is centrifuged, and the deposit taken up in 0.5-1.0 cc. cabol-saline. A slide agglutination test occupying one minute is then made with the five sera, representing most of the British strains. A definite reaction with any of these is indicative of the particular type. If the result is negative, cultures are prepared in 100 cc. of glucose broth, extracted, and tested by the contact method with a group serum known to be specific for *Streptococcus agalactiae* or Streptococcus Group B."

In Stableforth's test the difficulty of spontaneous agglutination has not been satisfactorily overcome, since it is this phenomenon which limits observations to a one-minute period. In this one-minute observation time weakly agglutinable strains are evidently missed, and a retest is necessary. In the microscopic agglutination tests the suspensions are stable, with very few exceptions; and weakly agglutinable strains can be appropriately identified. The incubation period is longer, obviously; but confirmatory or repeat tests are unnecessary. This accounts for much of the reduction in time when typing large numbers of strains.

The quantity of medium required in the test is another consideration which should be recalled. The rapid macroscopic agglutination test and the precipitin test of Lancefield require a minimum of 30 cc. of medium. As little as 1 cc. of blood-broth culture will provide sufficient antigen for the microscopic agglutination tests.

Cross tests with streptococci belonging to groups other than Group B have shown the specificity of the test, and biochemical confirmation with all isolated strains has served to prove its sensitivity.

It is possible that the test described here, in addition to its practical applications, might have taxonomical uses if different immunological methods were utilized and absorbed sera employed in the test. According to Lancefield (1934), specific type antibodies must be made by several series of injections with the group specific antibodies giving way to the type specific antibodies as the injections progress. Stableforth in his agglutination test for types used absorbed serums. However, in the detection of *Streptococcus agalactiae* as a species, serums of high group titre are preferable for the identification of all Group B strains isolated. Though a knowledge of the various subtypes of Group B is of significance to those interested in the epidemiology of mastitis infection, the classification of an isolated strain as a Group B microorganism would probably be sufficient from the standpoint of dairy and health laboratories. The practicability of the microscopic agglutination test in this regard is evident.

Conclusions

An attempt to adapt Neufeld's capsule swelling to Group B streptococci failed for lack of a method of rapidly inducing consistent capsule formation in the species tested.

A rapid microscopic agglutination test for Group B streptococci is presented. The test has shown close correlation with biochemical tests for the identification of *Streptococcus agalactiae*.

The test was successful in identifying 98% of the freshly isolated strains of this microorganism. This efficiency is attributed to the methods employed in obviating the difficulties of spontaneous agglutination which are inherent in cultures of streptococci.

There is a suggestion that data assembled by the use of the microscopic agglutination test is in accordance with the conclusions of Stableforth in his work on the etiology of mastitis.

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SECTION ON BOTANY

Chairman: FLOYD E. BEGHTEL, Evansville College

The papers published below, in full or in abstract form, were presented in the sectional program. Dr. Winona H. Welch, of DePauw University, was elected chairman of the section for 1939.

ABSTRACTS

A comparison of market milk from ten Indianapolis companies by use of the direct microscopic method of analysis. INA STANLEY, Butler University.—One quart bottle of milk, delivered by each of ten companies to homes, was used for this analysis. This was done in July, 1937, and repeated in September, 1937. Both plate and direct microscopic methods were used. Plate counts for July ranged from 4,000 to 120,000; for September from 1,000 to 198,000. Six companies showed increase in September over July and four showed decrease. Direct counts for July ranged from 8,100,000 to 31,910,000 and in September 2,840,000 to 20,930,000. From the direct counts all companies showed decrease in September as compared with July. Staphylococci were the most abundant form of organism in three companies for both July and September and in two additional companies for September. In all other cases diplococci were the most abundant type. Tables are presented showing number of staphylococci, diplococci, long streptococci, short streptococci, body cells, and fungi for each sample of milk studied. Significance of large numbers of each type of organism in terms of milk production and handling is discussed. The general conclusion is reached that in all cases quicker and better cooling methods are desirable and higher standards of cleanliness are necessary in the case of apparatus, especially in that used before the milk reaches the dairy.

A fossil pollen study of Kokomo Bog, Howard County, Indiana. JOHN W. HOWELL and RAY C. FRIESNER, Butler University.—The lower eleven feet of deposits show that a typical Canadian type of coniferous forest, dominated by *Abies* and *Picea*, was the pioneer after the soil was left by the glaciers. *Pinus* is the only other genus represented in the lower seven feet of deposits, but *Larix* is present in the deposits eight feet from the bottom. Twelve feet from the bottom, *Abies* and *Picea* lose dominance in favor of *Quercus* and *Betula*. Fifteen feet from the bottom, *Betula* begins to lose out, and *Quercus* retains undisputed dominance to the surface, never being approached by any other species. *Abies* and *Picea* drop out entirely a few feet after their dominance is lost, but *Pinus* remains in low frequencies to the first foot below the surface. *Larix* continues until within 12 feet of the surface and then disappears entirely. Broad-leaved trees in addition to those above mentioned were *Acer*, with a maximum of 10% in 10-foot level; *Carya*, 25% maximum at the 8-foot

level; *Fagus*, 5% maximum in the 2-, 4-, and 11-foot levels; *Juglans*, 12% maximum at the 1-foot level; *Populus*, 13% maximum in the 2-foot level; *Salix*, 9% maximum in the 19-foot level; *Tilia*, 5% maximum in the 10-foot level; and *Ulmus*, 16% maximum in the 16-foot level. The following forest succession is shown: *Abies-Picea*, *Abies-Picea-Larix*, *Quercus-Betula*, *Quercus-Carya*, *Quercus-Betula*, *Quercus-Juglans-Carya*. (Butler Univ. Bot. Stud. 4:117-127. 1938.)

Prominent European botanists and herbaria. WINONA H. WELCH, DePauw University.—A brief story of a study of some European herbaria, with slides showing well-known botanists and herbaria.

Forest succession in the southern limits of early Wisconsin glaciation as indicated by a pollen spectrum from Bacon's Swamp. JAMES H. OTTO, Butler University.—Forest succession in the Bacon's Swamp region since Pleistocene times was determined by analysis of fossil pollen preserved in peat and marl deposits in the bog. Bacon's Swamp is a significant station because of its location near the southern limits of early Wisconsin glaciation. Samples from two borings, one 32, the other 22 feet in depth, were examined. Forest succession was from *Abies-Picea* while early deposition was in progress, to mesophytic *Acer-Fagus-Quercus* forest of the present day. Climatic periods indicated are cool moist, moderately dry, warm with increased dryness, and warm moist. Results from the two borings correlated well. Results were similar to those from other bogs of early Wisconsin depositions. (Butler Univ. Bot. Stud. 4:93-115. 1938.)

Additional records for some of the less common algae. C. MERVIN PALMER, Butler University.—New localities are here reported for several American algae. Included are several forms not frequently encountered, such as *Desmonema* and *Hydrurus* from California, and *Nostochopsis*, *Nodularia*, *Colacium*, *Stichococcus*, *Chlorotylum*, *Compsopogon*, *Mischococcus*, and *Mesotaenium* from Indiana.

Notes on an early and little known Indiana botanical journal. LAWRENCE J. KING, Earlham College.—A search into the literature of Wayne County botany has revealed an almost unknown publication containing a number of papers on the flora of Indiana. This journal, the *L. B. Case Botanical Index*, was first published in Richmond, Indiana, in April, 1877, shortly after the establishment of the *Botanical Gazette* by John M. Coulter at Hanover in November, 1875. It was published quarterly for about four years. The early issues were scarcely more than trade catalogs, but, with the withdrawal of Mr. Case from business in 1880, the journal became more truly scientific. It was illustrated profusely with woodcuts. The circulation reached 5,000. The publication was suspended with the March, 1881, number (Vol. 4, No. 2). Lucien B. Case, the editor and publisher, was a prominent florist at that time and was active in scientific circles in his own community and the state as well. He was the corresponding secretary of the Richmond Scientific Association for several years, and he also served as the first secretary of the Indiana Archaeological Association. While the journal was largely horticultural in nature in the early issues, many items of a more

strictly botanical character were included in the later numbers. Of the articles published, two by W. C. Steele are of particular importance: "The Orchidaceae of Northern Indiana," and "A Brief Note on the Ferns of the Vicinity of La Porte, Indiana." Mrs. M. P. Haines' list of "Musci, Hepaticae, and Filices in the Vicinity of Richmond, Indiana," republished later in a modified form in the Indiana Geological Report in 1879, was also included here. Two articles on the "Big Trees of Indiana," one by B. W. Smith and the other by an anonymous writer, conclude the list of the more important contributions published in the *Index*.

Microclimate, evaporation, and epiphytic mosses. J. E. POTZGER, Butler University.—A comparison is made of trees on the Butler University campus and a typical beech-maple woods on the Fort Harrison reservation. Atmometers were placed at the bases and at a height of six feet on the north and south sides of trunks of trees in upland environment and in shallow ravines. For a period of 16 weeks the south sides had greater evaporation than the north, and higher parts of the trunks greater than the bases. Trees growing on ridges on the Butler campus showed greater evaporation than those similarly located at Fort Harrison. Local environmental influences frequently obliterated the effects of exposure and topography. (Bryologist, 1939.)

A quantitative study of the phytoplankton of Lake Michigan collected in the vicinity of Evanston, Illinois. WILLIAM ALLEN DAILY, Butler University.—A weekly quantitative study of the phytoplankton of Lake Michigan at Evanston, Illinois, was made over a period of one year, May, 1937, to May, 1938. Several ecological factors were studied in conjunction with the seasonal periodicity of the phytoplankton, e. g., temperature, turbidity, hydrogen-ion concentration, bacteria, and sunlight. The Sedgwick-Rafter method was used in the study. Forty-three genera representing five classes were recorded. In order of numerical abundance, the classes were Bacillariophyceae, Chrysophyceae, Myxophyceae, Chlorophyceae, and Dinophyceae. There was a considerable weekly variation and a marked seasonal periodicity in the total phytoplankton and in its variety. Strong maxima were noted in June and October. The diatoms dominated the phytoplankton at all times, both in total number and in number of species. (Butler Univ. Bot. Stud. 4:65-83. 1938.)

A test-tube spiral absorption vessel. RAYMOND E. GIBTON, Purdue University.—An efficient and compact carbon-dioxide absorption vessel has been designed for experiments in plant respiration. A test tube and a two-holed rubber stopper enclose the system. A vertical inlet tube carries the air stream to the bottom of the test tube where it is released in the form of small bubbles. These are caught and travel upward through the absorbent solution, in a submerged spiral glass tube. A short outlet tube carries the air stream out of the vessel after the spiral has been traversed.

A pollen profile of Otterbein Bog, Warren County, Indiana. RUTH R. RICHARDS, Butler University.—The bog was filled in forty-four feet,

of which twelve feet were marl. Pollen in the lower nine feet indicates an *Abies-Picea-Pinus* dominance. *Picea* and *Pinus* persisted in small percentages to the surface, while *Abies* disappeared at the 15-foot level. *Salix* had a higher percentage of pollen at the 34-foot level than any other genus, while the three conifers here showed a sharp decline. *Quercus* was the most important genus from the 32-foot level to the surface. *Acer* was most prominent at the 13- and 18-foot levels. The top levels indicate a *Quercus-Carya* climax with an *Ulmus* subclimax.

Notes on Indiana grasses. J. E. POTZGER, Butler University, and CHARLES M. EK, Kokomo.—A list of grasses from counties from which they have not previously been reported.

A modification of the Osterhout apparatus for the measurement of plant respiration. CLINTON H. HOBBS, Purdue University.—The Osterhout apparatus, as originally designed, did not give results within a range of 5% when used in measuring plant respiration. A modification of the apparatus involves a colorimetric determination of the production of carbon dioxide by a photoelectrical method. Data are presented which show the greater accuracy of the modified apparatus.

The malachite-green differential culture-test as applied to sex-reaction strains of *Nectria coccinea*. M. L. LOHMAN and WILMA E. BURMAN, Indiana University.—Sexual reaction strains of a fungus diagnosed as *Nectria coccinea* (Pers.) Fr. (in the sense of Wollenweber) were grown on a special nutrient agar medium containing malachite green in concentrations ranging from 0.125 to 1.0 p.p.m., to determine the relationship of physiological culture types to known dye-toxicity values for the fungus. Colony diameters of plate cultures, with and without the dye, were recorded on the 10th and 15th days. Nearly identical toxicity values were found for all cultures of both strains when growth was inhibited by moderately to strongly toxic concentrations of the dye. The calculations indicate that, for the culture conditions maintained, a concentration of 0.00022% dye would be required to reduce growth to 25% of that on the control medium. However, inhibition values for the weaker concentrations studied showed a wide range since the cultures were either stimulated or inhibited in growth in varying degrees. With these concentrations some tendency to a differential response by strains was evident.

The anatomy of the leaf of *Streptochaeta spicata*, a tropical grass. PAUL WEATHERWAX, Indiana University.—The mature leaf of *Streptochaeta spicata* has in the mesophyll a series of air spaces apparently unlike any which have thus far been reported. These are formed from a special layer of parenchyma cells which thicken their walls and collapse as they die, forming a number of structures similar to steel I-beams.

Leaf-spot of Black Cherry

ROBERT E. WEAN, Purdue University

In order to determine if initial penetration of leaf tissue on *Prunus serotina* Ehrh. occurred through the upper or lower leaf-surface, a conidial spore suspension (the *Cylindrosporium* stage) was secured by scraping spores from diseased leaves. The solution was then applied by means of a camel's hair brush to the upper epidermis of fifteen healthy leaves and to the under surface of fifteen similar leaves. Young nursery seedlings of current season's growth were utilized, and leaves of corresponding size and age were used on the various plants.

Following an inoculation period of fifteen days the treated leaves were removed from the plants and the lesions of infection counted. Upper leaf-surface inoculations yielded an average of 18.2 lesions per leaf, while upon those of under-surface treatment there were 85.3 lesions per leaf. Furthermore, at the end of this period many of the lesions on the under leaf-surface were in a conidial fruiting stage, while those of the other type were much less advanced and showed little fruiting. A duplication of this experiment gave similar results. It follows, therefore, that in applying sprays for the control of this disease, caused by *Coccomyces* sp., particular care should be taken to secure good coverage of the lower leaf-surface with a fine mist or fog spray.

Little or no attention has been given to determine a suitable spray solution for protecting nursery stock of *P. serotina* from infection by this fungus. The use of this tree species in reforestation warranted



Fig. 1. Center foreground, plot receiving lime sulphur plus ferrous sulphate; control area in center background. Plot to the right received Bordeaux mixture 2-3-50.

experimental work in this direction. It was found that lime sulfur 1-50 plus one and one-fourth pounds of ferrous sulphate was entirely impractical for use on seedling plants. Despite the previous recommendation of this solution¹ all of the plants in this experimental plot were either severely stunted or killed outright (Fig. 1). Two sprays which gave favorable results, using the criteria of foliage protection and freedom from unfavorable affects on plant growth, were copper phosphate and Bordeaux mixture.

The copper phosphate spray was composed of copper phosphate, two pounds, hydrated lime, four pounds, bentonite, two pounds, and water, fifty gallons. (With hand operated sprayers some difficulty is encountered in keeping the solution sufficiently agitated to yield a uniform spray.) The Bordeaux was a standard 2-3-50 formula. Neither of the above sprays entirely prevented leaf infection although seven applications were made at weekly intervals. However, infection in neither case was sufficient to cause premature leaf-fall during the actively growing season for the plant. From the various solutions tested, including several commercial sulfurs, the copper compounds indicate that with further research a successful spray can be developed for the control of leaf-spot on black cherry.

¹ Hesler, L. R. and H. H. Whetzel. 1924. Manual of fruit diseases. p. 176. Macmillan, New York.

A Phytosociological Study of the Woody Plants Constituting Twenty-five Type Forests of the Illinoian Till Plain in Indiana

SCOTT MCCOY, Arsenal Technical H. S., Indianapolis

Introduction

Plant sociological studies have held the attention of European students of plant life for many years but have had little consideration in the United States until recent times when H. S. Conard and Stanley A. Cain gave this study of plant life impetus.

Many of American studies of the relationship of plants to their habitat were published under generalized headings of ecological survey; and they were usually extensive rather than intensive, empirical rather than quantitative, and so were not very analytical. This is especially true for Indiana, which Friesner (1937) has aptly called "a critical botanical area." For here are limits of extension of plants from every cardinal point of the compass. It was frequently assumed that because Indiana is a more or less uniform till plain, especially when viewed on a map, the plant cover should also be more or less homogeneous and uniform. That is, however, an erroneous conception, especially when forest types within the deciduous forests are involved. Potzger (1937) has shown that microclimate or local climate is sufficiently important to vary expression in oak-hickory or beech-maple type by the small difference of north or south exposures of ridges.

The present study is concerned with the forests on the topographically uniform Illinoian till plain which has an eastern and western lobe extending southward beyond the later-deposited Wisconsin glacial till. A considerable portion of the eastern lobe is known as the "flats" area. The soil is more or less uniform, and so one might expect a striking uniformity in forest type.

Various plant geographers of the past apparently considered such an assumption the true status.

Weaver and Clements (1929) give two particular climax forest types as applicable to the general region under study, these being the beech-maple and oak-hickory types.

A committee of the Society of American Foresters (1932) places the "flats" of Indiana into the beech type of forest, the beech being pure or predominating.

Zon (1924) placed practically all of Indiana into the oak-hickory type of forest. Such a classification was based on little field study and so has given an incomplete picture of our Indiana forest climaxes.

Gordon (1936) states that the north-central part of Sullivan County, where three of the western lobe forests under study are located, has pure stands of beech, beech-sugar maple, and beech-sugar maple-yellow popular types. Practically all the forests on the eastern lobe, considered in this paper, fall into his beech-sweet gum district. All of these classifications are incorrect, as subsequent data will show.

It is, thus, apparently assumed that the homogeneous Illinoian till plain is characterized by a homogeneous vegetation cover. Investigation of the concepts frequency, density, and fidelity promised most information on the true relationships with respect to the woody species constituting the forests on the Illinoian till plain in Indiana; and so these concepts were stressed in the present study.

The concept fidelity is used here in a modified sense from that given it by Braun-Blanquet and Pavillard. It is used as referring to the regularity of occurrence of a species in twenty-five similar habitat sites but not necessarily with similar vegetation complex, and its degree is expressed in percentage. It is thus, a modification of the diagram presentation of the same concept by Sampson (1930).

Geologic and Physiographic History

The two regions under study are located on the Illinoian till plain, one on the eastern side of the state comprising most of Jackson, Jefferson, Jennings, and Ripley counties and the other on the western side in Davies, Greene, Sullivan, and Vigo counties (Figure 1).

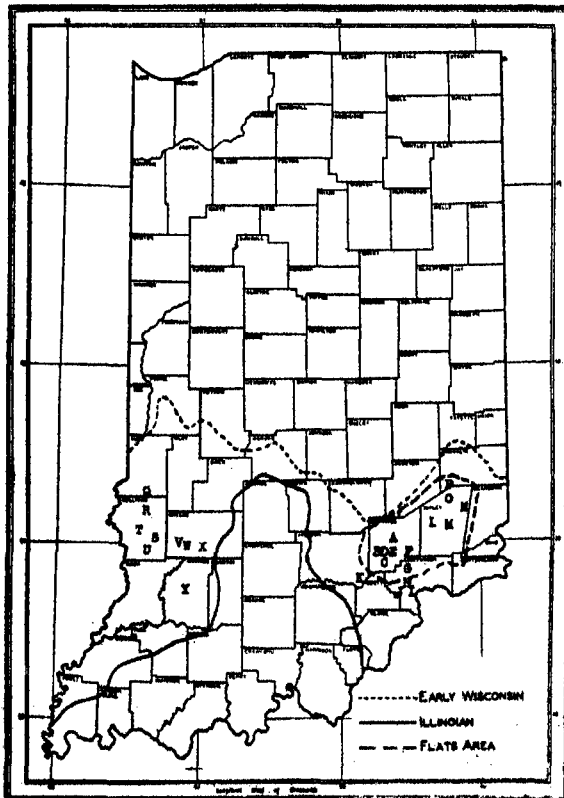


Fig. 1. Glacial boundaries, extent of the "flats" area, and locations of the forest sites studied.

The geologic and physiographic history of Indiana is probably more diverse and complex than one might assume from casual observation and is due to a number of significant geological phenomena of the past, such as series of uplifts and subsequent levelings and periodic crustal stability during which time denudation took place. During Pleistocene times continental glaciation modified most of Indiana and obliterated much of the erosional surface features formed after the Cincinnati Arch uplift. Three glacial invasions are recognized, viz., the Illinoian, Early, and Late Wisconsin. Of these, the Illinoian was the most extensive, reaching the Ohio River but leaving a large triangular area in the south-central part comprising approximately 6,250 acres unglaciated. Most of the surface evidence of the Illinoian glaciation was covered by the moraines and till of the two Wisconsin ice sheets. The two lobes of the Illinoian till plain which are still exposed comprise 3,100 square miles in the eastern lobe and 4,100 square miles in the western lobe (Malott 1922). The soil is extremely leached, consisting chiefly of a whitish clay with usual poor drainage. The monotonously featureless plain of the eastern lobe has coined for it the term "flats" area. Although, as a whole, the western area has a somewhat better drainage, it has essentially the same soil characteristics so that one might suggest a western "flats" area.

Climatic Factors

The climate always presents an important group of factors affecting vegetation, and the areas under study are no exception. The precipitation and temperature data for the areas under study were compiled from the work of Martin (1933), data taken from weather bureau stations nearest a respective group of forests.

Edaphic Factors

The typical soil structure of the Illinoian glacial drift is a compact whitish clay, and most of the soil where the twenty-five forests under study were located was of this type. Variants of other soil types were a yellowish clay, sandy clay mixture, grayish clay, and a black loam.

This whitish clay soil has a tendency to become rather compact at the surface and to form a hardpan layer beneath. The very fine texture of the soil and the presence of the hardpan layer permit only a limited amount of subsoil drainage.

There was very little surface drainage in most of the twenty-five forests. The rather level topography and the compactness of the soil are pertinent factors in making the soil water-logged. In general, roadside and other drainage ditches have had some effect on the water table level.

Methods and Type Forest Locations

Twenty-five forests, sixteen on the eastern lobe and nine on the western lobe, were selected for this study. It was attempted to select the most representative and least disturbed forests of the Illinoian till plain which could be found.

Twenty quadrats, ten by ten meters, were run in each of these

forests. Usually two lines of ten quadrats each were run. All woody stems one inch and over DBH. were measured. All stems three feet and over in height were included in the density tabulation. The shrubs were tabulated for frequency but not for density. Deam's books (1924, 1931) on Indiana shrubs and trees were the chief sources of the nomenclature used.

All the forests on the eastern lobe of the till plain, with the exception of forests J and P, are on very level lands with practically no surface drainage. Most of these are in the so-called "flats" area of eastern Indiana. Here the glacial drift (Malott, 1922) varies in depth from practically nothing, where it has been removed by subsequent erosion, to over 100 feet. On the average it is less than 25 feet in depth. Much of the drift-covered portion of southeastern Indiana is exceptionally flat, still exhibiting the characteristics of a featureless ground moraine. The deeper drift occupies the pre-glacial valleys.

Topography where the forests on the western lobe are located is similar to that of the eastern lobe with the exception of forest R, which has rather good surface drainage, and X, which has excellent surface drainage.

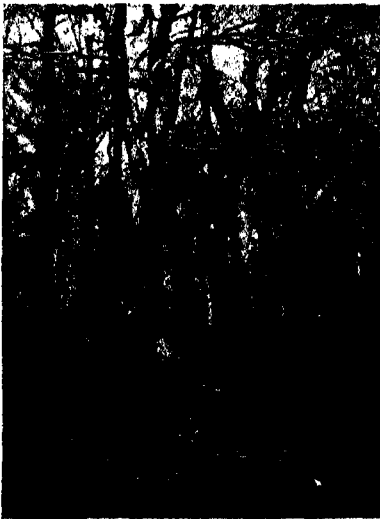


Fig. 2. Some of the few beech present in forest T, Sullivan County. (All photographs by Dr. J. E. Potzger, Jan. 31, 1938.)



Fig. 3. Open park-like area in Forest T, Sullivan County. Pasturing has reduced the number of young stems.

Observations and Results

Precipitation and temperature.—The records which were consulted for these two areas covered, in most cases, more than 30 years and in some cases up to 45 years, all terminating with the year 1930. These records show very little difference in the average monthly and annual precipitation for the two areas. The average annual precipitation for

the eastern lobe is 42.95 inches and that for the western lobe 39.10 inches, a difference of 3.85 inches in the annual precipitation; however, for the growing season from April to September, inclusive, there is a difference of only 0.83 inches, this in favor of the eastern lobe.

The records for average temperature show even less difference between the two areas. For March, May, and September it is the same for both lobes for the months February, April, June, July, August, and November there is a difference of only .3 of a degree or less.

Soil.—County location (Fig. 1) and brief description of the 25 type forests follow:

Forest	County	Soil	Surface Drainage	Disturbance
A	Jennings	fine light clay	little	none
B	Jennings	fine whitish clay	good	none
C	Jennings	fine whitish clay	poor	severe pasturing
D	Jennings	fine whitish clay	fair	very little
E	Jennings	fine whitish clay	very little	none noticed
F	Jennings	fine whitish clay	very little	some, years ago
G	Jefferson	fine whitish clay	good	very little
H	Jefferson	fine whitish clay	very poor	very little
I	Jefferson	fine whitish clay	very poor	completely cut over 28 years ago, now cattle range
J	Jefferson	yellow clay type	very good	none
K	Jackson	fine whitish clay	none	slight cutting
L	Ripley	fine whitish clay	some	pasturing and cutting
M	Ripley	fine whitish clay	very little	years ago, cutting
N	Ripley	fine whitish clay	fair	pasturing and cutting
O	Ripley	fine whitish clay	very little	some recent cutting
P	Franklin	yellow clay	very good	cutting, years ago
Q	Vigo	gray clay	very little	some cutting
R	Sullivan	gray clay	rather good	cutting, years ago
S	Sullivan	light gray clay	very little	very little
T	Sullivan	light gray clay	rather good	pasturing
U	Sullivan	gray clay	fair	pasturing
V	Greene	black loam	none	very young forest, no recent disturbance
W	Greene	light clay	none	pasturing and cutting
X	Greene	sand clay mixture	good	pasturing
Y	Daviess	black loam	fair	by flood waters

The soil, with the exception of that in forest J on the eastern lobe and probably V and X on the western lobe, is practically of the same whitish texture, which in level uneroded sites makes for water-logged conditions. That the soil is water-logged at times is shown by the shallow root systems of such trees as beech and elm, many of their roots having their upper surfaces above the ground for some distance from the tree trunks (Fig. 4). Braun (1936) reports this same condition in certain forests on the Illinoian till plain in Ohio.

No tests were made for soil acidity on the western lobe, but the author (1937) found that the acidity for the soil in forest F on the eastern lobe ranged from pH 4.8 to 5.6 at the surface, 4.8 to 5.4 at

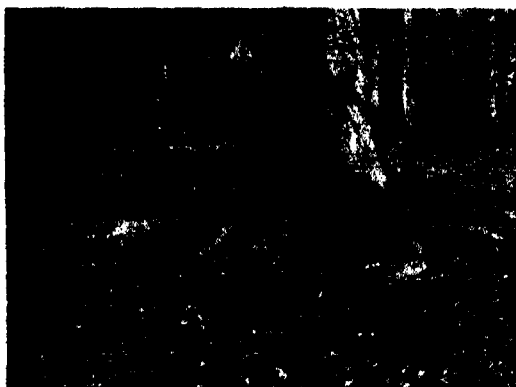


Fig. 4. Showing exposure of beech roots in forest T, Sullivan County.

the three-inch level, and 4.5 to 5.2 for the twelve-inch level. Braun (1936) reported practically the same acidity range for the soil in similar areas in Ohio.

Size classes of the woody plants; frequency, fidelity, density.—The results of the field study relative density, DBH., and subsequent division into size classes are given in Tables I to V, inclusive. The frequency and density of species in the large tree class for both lobes are shown in Table VI. The fidelity of the species in the large tree class for both lobes is shown in Table VII. The frequency and fidelity of species occurring in areas with good and poor surface drainage on both the eastern and western lobes are shown in Table VIII.

TABLE I.—Size Classes, Forests A to E

Species	A						B						C						D						E					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
Acer rubrum.....	202	132											1	1	1										2	3	9	8	2	
A. saccharum.....							584	63		1									96	56	6	1	1	1	31	10				
Carya cordiformis.....																									6					
C. glabra.....																									2		1			
C. laciniosa.....	6						3												1											
C. ovata.....	16	7					5	3					3	2	2	1	14								113	25	5	1		
Fagus grandifolia.....							153	16		1	9	3	5	2	24	22	77	21	1	2	6	2			73					
Fraxinus americana.....							1	1		1															15	1				
F. biltmoreana.....							50	4					1						17	22										
F. lanceolata.....							35	7											15	14					95					
F. nigra.....		1																												
Juglans nigra.....								1		1																				
Liquidambar styraciflua.....	16	110	9				72	3			1	1	5	6	1	1	6		9	3	1				4	2	5	8	1	
Liriodendron tulipifera.....							18	15				1							5											
Nyssa sylvatica.....	29	68					1	1					1						1	1					13	6	7	1		
Platanus occidentalis.....		2								1																				
Prunus serotina.....	1						8												3	2										
Quercus alba.....		5	2				1																		48	3				
Q. bicolor.....																									2					
Q. borealis maxima.....																			1											
Q. palustris.....	9	60	54	2																										
Q. velutina.....	1	4																												
Ulmus americana.....							9	1																						
U. racemosa.....	210	109											5	2					3	9	2	1			18				1	

a—under 1 inch DBH.
b—1 to 5 inches DBH.

c—6 to 10 inches DBH.
d—11 to 15 inches DBH.

e—16 to 25 inches DBH.
f—over 25 inches DBH.

TABLE II.—Size Classes, Forests F to J

Species	F						G						H						I						J					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
Acer rubrum	91	112	4	1			19	9					19	26	9	8			1	6	7				7	5				
A. saccharum		2					30	1																	121	102	2	1	1	
Carya cordiformis																														
C. glabra																									23	28	5	4		
C. laciniosa							1						4							3										
C. ovata	24	19					76	41					8							6	1				10	10	3			
C. tomentosa																				3					2					
Fagus grandifolia	6	16	2				305	51		1	12	1	163	30	1	1	8	1							27	36	2	2		1
Fraxinus americana							3																							
F. biltmoreana													6	1	1										16	3				1
F. lanceolata	3	7																							12					
F. nigra													1																	
F. profunda	1																													
Juglans nigra																														1
Liquidambar styraciflua	32	104	3	2			421	130			2	2		12	3	7	3	1	1	9	164	75	1							
Liriodendron Tulipifera	33	63	1	1			10	18	6	3			8	1	1	1														2
Nyssa sylvatica	45	34	2				7	3					35	13	5	1	1	1	34	216	6					4	2	2		
Platanus occidentalis		2																					1							
Prunus serotina	3	2					31	9	1				1													8	1			
Quercus alba		3					14	8	3				17	7						22	20					9	21	6	2	3
Q. bicolor							4													9	11									
Q. borealis maxima	2	3					2	1					8	1	2					3	1					1	4			
Q. palustris	7	36							1				1			1														
Q. Prinus	1	1					8	4			1			2	1					1	6									
Q. velutina																														
Ulmus americana	19	16	1											1														1	2	3
U. fulva																										3	3			
U. racemosa	5	9	1	1			35	26	2				12	9	1					5	3	1								

a—under 1 inch DBH.
b—1 to 5 inches DBH.

c—6 to 10 inches DBH.
d—11 to 15 inches DBH.

e—16 to 25 inches DBH.
f—over 25 inches DBH.

TABLE III.—Size Classes, Forests K to O

Species	K						L						M						N						O						
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	
Acer rubrum	284	5	5		1			1	3	4	3		6	7	9	6			1		4	2			16	6	2	1			
Carya laciniosa	10	2																													
C. ovata	11	2					2				1	1		5		1	3		36	5	1		4		43	8					
Fagus grandifolia			1	5	7			2	2	10	10		12	38	1	7	12		37	7	2	6	19	3	70	12	11	15	4		
Fraxinus americana																			6	2					38	8		1	1		
F. lanceolata							1																								
F. profunda															3	1															
Liquidambar styraciflua	115	14	3	2					1						5	3			26	7	4	8	1	2	61	4	2	7	1	1	
Liriodendron tulipifera																3															
Nyssa sylvatica	77	10	1	2				3	1	1				4	1	1	1		1		2	6					1	2			
Prunus serotina	9																		8	4			4		36	12	4	1			
Quercus alba	30	42		2				4	4	4	2			1	1	1	1						1		3						
Q. bicolor		7																							2						
Q. borealis maxima	16	10	1		1									3																	
Q. palustris	14	13	2	2	1					2	2	6		2	1	1	2	2							3	1	1		2	2	
Q. velutina																															
Ulmus americana																															
U. racemosa	2	6						2						6	1	1				3	1				39	21	2		1	2	

a—under 1 inch DBH.
b—1 to 5 inches DBH.

c—6 to 10 inches DBH.
d—11 to 15 inches DBH.

e—16 to 25 inches DBH.
f—over 25 inches DBH.

TABLE IV.—Size Classes, Forests P to T

Species	P						Q						R						S						T					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
Acer rubrum												1	4		1	5	1													1
A. saccharum	227	82	2	1			2											1							59	5	1	2	2	
Carya cordiformis	1																	1												
C. glabra	2	2	2	1	3																									
C. lucinosa							11			2			15	18			1		5	1					6					
C. ovalis								1			1			1							2	3	2							
C. ovata	4	2					23	3	5	1	1		16	8			1		4	21	2	4			8	9	7	3	1	
C. tomentosa		9	4	3	1		23	1	5	7	1	2	2				1													
Celtis occidentalis							12																							
Fagus grandifolia	22	8	1	3	10	1																			3	1	1	1	8	
Fraxinus americana	19	7	1	1			17	1					25	34	1				1	2	1									
F. lanceolata							25	5	1					3	1				24	2					54	5	3	1	1	
F. profunda													22	5																
Gleditsia triacanthos																	2													
Juglans nigra							7	3								5		2								2	1	2		
Liquidambar styraciflua						1																				3	3	4	8	
Liriodendron tulipifera		3	6		1	1	11					1																		
Nyssa sylvatica	56	25	4	1	5	1	8	2							1				32	21	5									
Prunus serotina	14	15					30	13					32	19					5											
Quercus alba													13	2	1	2	2	1			3	6	7	6		2	1			
Q. bicolor													2	2							4	1	3	1						
Q. borealis maxima																														
Q. imbricaria		2		2	1																									
Q. palustris																														
Q. velutina		1	3				2	1	2	2	8	1	3				2	5											1	4
Ulmus americana			1	1			13	2					66	12																
U. fulva		2											56	10					3							5		2	3	1
U. racemosa							3	2					37	40					2	2	1					29	6	2	3	

a—under 1 inch DBH.
b—1 to 5 inches DBH.

c—6 to 10 inches DBH.
d—11 to 15 inches DBH.

e—16 to 25 inches DBH.
f—over 25 inches DBH.

TABLE V.—Size Classes, Forests U to Y

Species	U						V						W						X						Y						
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	
Acer rubrum				1									4	5														61	26	4	3
A. saccharum							72	55	21	2	3																				
A. saccharum	4			1																											
Carya cordiformis							4																								
C. glabra																															
C. ovata	52	76	19				2	1					93	21		1	5	1	12	46	6	1				2			1		
C. tomentosa													1	1																	
Fagus grandifolia																															
Fraxinus americana																			23	11	16	2	2								
F. biltmoreana																															
F. lanceolata													1						3		3		1								
F. profunda							56	54	4	2																	93	24	15	3	
F. quadrangulata							1																								
Gleditsia triacanthos								4	2																						
Liquidambar styraciflua																															
Nyssa sylvatica	38	15	6	1															1	2	2										
Platanus occidentalis							1																				1		1	1	
Populus heterophylla											1																				
Prunus serotina	28	5											42	11																	
Quercus alba																															
Q. bicolor				1	1								18	7	5	11	1	1													
Q. borealis maxima													1																		
Q. imbricaria													34	19		5	4														
Q. Muhlenbergii																															
Q. palustris																															
Q. stellata							45	99	18		1		24	32		2	1														
Q. velutina	1																														
Ulmus fulva																															
U. americana	38	3					19	29	5	1	1		18	21					24	30	1						33	21	4	1	2
U. americana																															

a—under 1 inch DBH.
b—1 to 5 inches DBH.

c—6 to 10 inches DBH.
d—11 to 15 inches DBH.

e—16 to 25 inches DBH.
f—over 25 inches DBH.

TABLE VI.—Frequency and Density of Species in the Large Tree Class Occurring in 16 Type Forests (Eastern Lobe) and 9 (Western Lobe) of the Illinoian Till Plain in Indiana.

Species	Eastern Lobe		Western Lobe		Total Both Areas	
	F. I.	Density	F. I.	Density	F. I.	Density
<i>Acer rubrum</i>	43.8	1,054	16.7	118	34.0	1,172
<i>A. saccharinum</i>			8.9	156	3.2	156
<i>A. saccharum</i>	30.6	1,412	15.0	240	25.6	1,652
<i>Carya cordiformis</i>	2.2	9	5.0	15	3.2	24
<i>C. glabra</i>	9.7	75	6.1	22	8.4	97
<i>C. laciniosa</i>	5.6	34	10.0	59	7.2	93
<i>C. ovalis</i>			3.3	10	1.2	10
<i>C. ovata</i>	41.6	569	53.9	407	46.0	976
<i>C. tomentosa</i>	.6	9	9.5	65	3.8	74
<i>Celtis occidentalis</i>			2.2	12	.8	12
<i>Fagus grandifolia</i>	71.9	1,421	6.1	18	48.2	1,439
<i>Fraxinus americana</i>	13.8	115	17.8	128	15.2	243
<i>F. biltmoreana</i>	12.5	125	.6	1	8.2	126
<i>F. lanceolata</i>	17.0	267	22.2	55	18.6	322
<i>F. nigra</i>	1.6	5			2.8	5
<i>F. profunda</i>	1.3	5	22.8	278	9.0	283
<i>F. quadrangulata</i>	.3	1	.6	1	.4	2
<i>Gleditsia triacanthos</i>			1.7	9	.6	9
<i>Juglans nigra</i>	1.0	3	2.2	22	1.4	25
<i>Liquidambar Styraciflua</i>	55.6	1,506	9.5	22	39.0	1,528
<i>Liriodendron Tulipifera</i>	20.9	212	4.4	18	15.0	230
<i>Nyssa sylvatica</i>	46.3	704	16.7	130	35.8	734
<i>Platanus occidentalis</i>	1.6	5	2.2	5	1.8	10
<i>Populus heterophylla</i>			1.7	3	.6	3
<i>Prunus serotina</i>	16.6	120	17.8	173	17.0	293
<i>Quercus alba</i>	33.1	238	26.1	137	30.6	375
<i>Q. bicolor</i>	3.4	49	17.2	60	8.4	109
<i>Q. borealis maxima</i>	17.5	75	6.1	12	13.4	87
<i>Q. imbricaria</i>			18.0	95	6.4	95
<i>Q. Muhlenbergii</i>			.6	1	.2	1
<i>Q. palustris</i>	19.1	229	26.6	268	21.8	497
<i>Q. Prinus</i>	3.8	18			2.4	18
<i>Q. stellata</i>			1.7	4	.6	4
<i>Q. velutina</i>	4.1	26	17.2	54	8.8	80
<i>Ulmus americana</i>	7.5	120	9.4	102	8.2	222
<i>U. fulva</i>	1.9	8	15.0	134	6.6	142
<i>U. racemosa</i>	36.2	491	45.5	341	39.6	832
Total Density.....		8,805		3,175		11,980

TABLE VII.—Fidelity (in per cent) of Woody Species, Large Tree Class, Constituting 25 Type Forests of Illinoian Till Plain in Indiana.

Species	Eastern Lobe	Western Lobe	All Areas
<i>Acer rubrum</i>	81	77	80
<i>A. saccharinum</i>		11	4
<i>A. saccharum</i>	44	55	48
<i>Carya cordiformis</i>	19	44	28
<i>C. glabra</i>	25	11	20
<i>C. laciniosa</i>	44	44	44
<i>C. ovalis</i>		33	12
<i>C. ovata</i>	100	100	100
<i>C. tomentosa</i>	6	44	20
<i>Celtis occidentalis</i>		11	4
<i>Fagus grandifolia</i>	88	33	68
<i>Fraxinus americana</i>	38	55	44
<i>F. biltmoreana</i>	50	11	36
<i>F. lanceolata</i>	38	66	48
<i>F. nigra</i>	19		12
<i>F. profunda</i>	12	33	20
<i>F. quadrangulata</i>	6	11	8
<i>Gleditsia triacanthos</i>		33	12
<i>Juglans nigra</i>	12	33	20
<i>Liquidambar styraciflua</i>	94	22	68
<i>Liriodendron tulipifera</i>	69	22	52
<i>Nyssa sylvatica</i>	100	55	84
<i>Platanus occidentalis</i>	25	33	28
<i>Populus heterophylla</i>		22	8
<i>Prunus serotina</i>	75	77	76
<i>Quercus alba</i>	88	88	88
<i>Q. bicolor</i>	25	44	32
<i>Q. borealis maxima</i>	81	33	64
<i>Q. imbricaria</i>		44	16
<i>Q. Muhlenbergii</i>		11	4
<i>Q. palustris</i>	50	55	52
<i>Q. prinus</i>	19		12
<i>Q. stellata</i>		11	4
<i>Q. velutina</i>	25	66	40
<i>Ulmus americana</i>	44	44	44
<i>U. fulva</i>	25	55	36
<i>U. racemosa</i>	75	100	84

Analysis of Table II shows that forest A, evidently a comparatively young forest, has 986 stems ranging in size up to 5 inches DBH., 67 between 6 and 15 inches, 65 of these being 10 inches or under. Forest B has 1,051 stems in the two lower size classes and only 20 stems above 5 inches DBH. In this forest the surface drainage is rather good. No pasturing has occurred in both of these forests so that reproduction is unhampered by cultural influences. Forest C is subjected to almost continual pasturing. Here are only 29 stems in the two lower size-classes and 68 in the upper classes, the majority being above 15 inches DBH. Forest E is a mature stand on rather level land. It has 472 stems in the two lower size-classes. Seventy-three of these are beech, indicating that beech is just coming in. Forest I was completely cut over 28 years ago, but the beech has not as yet come in although it is present

in the older forests in the vicinity. Here the oaks and sweet and sour gums are the dominant species. Forest J has excellent surface drainage, and here white and black oak and four species of *Carya*, namely *C. cordiformis*, *C. tomentosa*, *C. ovata*, and particularly *C. glabra*, are giving the beech and sugar maple serious competition. On the western lobe beech is poorly represented; the dominant species seem to be beech, oak, and hickory, with considerable sugar maple in a few forests. On the drier sites red elm may be found.

TABLE VIII.—The Frequency and Fidelity of Species Occurring in Areas with Good and Poor Surface Drainage on the Eastern and Western Lobes of the Illinoian Till Plain.

Species	Eastern Lobe				Western Lobe			
	Frequency Gullyng		Fidelity Gullyng		Frequency Gullyng		Fidelity Gullyng	
	Yes	No	Yes	No	Yes	No	Yes	No
<i>Acer rubrum</i>	16.7	60.5	50	100	8.3	20.8	66	83
<i>A. saccharinum</i>						13.3		17
<i>A. saccharum</i>	69.2	7.5	83	20	38.3	3.3	66	50
<i>Carya cordiformis</i>	3.3	1.5	33	10	11.7	1.7	66	33
<i>C. glabra</i>	22.5	2.0	33	20	18.3		33	
<i>C. laciniosa</i>	3.3	7.0	50	40	13.3	8.3	66	33
<i>C. ovalis</i>					1.7	4.2	33	33
<i>C. ovata</i>	41.7	41.5	100	100	63.3	49.2	100	100
<i>C. tomentosa</i>	1.7		17		10.0	9.2	66	33
<i>Celtis occidentalis</i>						3.3		33
<i>Fagus grandifolia</i>	85.0	64.0	100	80	15.0	1.7	66	17
<i>Fraxinus americana</i>	19.2	11.5	68	20	36.6	8.3	66	50
<i>Fraxinus biltmoreana</i>	27.5	3.5	68	30	1.7		33	
<i>F. lanceolata</i>	23.3	12.5	50	30	41.6	12.5	100	50
<i>F. nigra</i>		2.5		30	6.7	4.2	33	17
<i>F. profunda</i>		2.0		20	5.0	31.7	33	33
<i>F. quadrangulata</i>		.5		10		.8		17
<i>Gleditsia triacanthos</i>					1.7	1.7	33	33
<i>Juglans nigra</i>	2.5		33		6.6	1.7	33	33
<i>LiquidambarStyraciflua</i>	39.2	65.5	83	100	21.7	3.3	33	17
<i>Liriodendron Tulipifera</i>	27.5	17.0	100	50	5.0	4.2	33	17
<i>Nyssa sylvatica</i>	32.5	55.0	100	100	5.0	22.5	66	50
<i>Platanus occidentalis</i>	.8	2.0	17	30	1.7	2.5	33	33
<i>Populus heterophylla</i>						2.5		33
<i>Prunus serotina</i>	29.2	9.0	100	60	16.7	20.7	66	68
<i>Quercus alba</i>	26.7	32.0	83	90	33.3	22.5	100	83
<i>Q. bicolor</i>	.8	5.0	17	30	3.3	24.2	33	50
<i>Q. borealis maxima</i>	9.2	22.5	83	80	13.3	2.5	66	33
<i>Q. imbricaria</i>					1.6	25.8	33	50
<i>Q. Muhlenbergii</i>					1.6		33	
<i>Q. palustris</i>	.8	30.0	17	70	1.6	39.2	33	68
<i>Q. Prinus</i>	5.8	2.5	17	20				
<i>Q. stellata</i>						2.5		17
<i>Q. velutina</i>	10.0	1.5	33	20	30.0	18.3	100	50
<i>Ulmus americana</i>	10.0	6.5	87	10	20.0	4.2	66	33
<i>Ulmus fulva</i>	3.3	1.0	33	20	33.3	5.8	100	50
<i>U. racemosa</i>	21.7	44.0	50	100	41.6	47.5	100	83

A comparison of the frequency, density, and fidelity of the ten leading species on the two lobes is shown in Table IX.

TABLE IX.--Showing 10 Species Highest in Frequency, Density, and Fidelity.

FREQUENCY				
	Eastern Lobe		Western Lobe	
		Per cent		Per cent
1	<i>Fagus grandifolia</i>	71.9	<i>Carya ovata</i>	53.9
2	<i>Liquidambar Styraciflua</i> ...	55.6	<i>Ulmus racemosa</i>	45.5
3	<i>Nyssa sylvatica</i>	46.3	<i>Quercus palustris</i>	26.6
4	<i>Acer rubrum</i>	43.8	<i>Quercus alba</i>	26.1
5	<i>Carya ovata</i>	41.6	<i>Fraxinus profunda</i>	22.8
6	<i>Ulmus racemosa</i>	36.2	<i>Fraxinus lanceolata</i>	22.2
7	<i>Quercus alba</i>	33.1	<i>Quercus imbricaria</i>	18.0
8	<i>Acer saccharum</i>	30.6	<i>Prunus serotina</i>	17.8
9	<i>Liriodendron Tulipifera</i>	20.9	<i>Fraxinus americana</i>	17.8
10	<i>Quercus palustris</i>	19.1	<i>Quercus velutina</i>	17.2

DENSITY				
	Eastern Lobe		Western Lobe	
1	<i>Liquidambar Styraciflua</i> ...	1,506	<i>Carya ovata</i>	407
2	<i>Fagus grandifolia</i>	1,421	<i>Ulmus racemosa</i>	341
3	<i>Acer saccharum</i>	1,412	<i>Fraxinus profunda</i>	278
4	<i>Acer rubrum</i>	1,054	<i>Quercus palustris</i>	268
5	<i>Nyssa sylvatica</i>	704	<i>Acer saccharum</i>	240
6	<i>Carya ovata</i>	569	<i>Prunus serotina</i>	173
7	<i>Ulmus racemosa</i>	491	<i>Acer saccharinum</i>	156
8	<i>Fraxinus lanceolata</i>	267	<i>Quercus alba</i>	137
9	<i>Quercus alba</i>	238	<i>Ulmus fulva</i>	134
10	<i>Quercus palustris</i>	229	<i>Nyssa sylvatica</i>	130

FIDELITY				
	Eastern Lobe		Western Lobe	
1	<i>Carya ovata</i>	100	<i>Carya ovata</i>	100
2	<i>Nyssa sylvatica</i>	100	<i>Ulmus racemosa</i>	100
3	<i>Liquidambar Styraciflua</i> ...	94	<i>Quercus alba</i>	88
4	<i>Quercus alba</i>	88	<i>Acer rubrum</i>	77
5	<i>Fagus grandifolia</i>	88	<i>Prunus serotina</i>	77
6	<i>Acer rubrum</i>	81	<i>Fraxinus lanceolata</i>	66
7	<i>Quercus borealis maxima</i> ..	81	<i>Quercus velutina</i>	66
8	<i>Ulmus racemosa</i>	75	<i>Nyssa sylvatica</i>	55
9	<i>Prunus serotina</i>	75	<i>Quercus palustris</i>	55
10	<i>Liriodendron Tulipifera</i>	69	<i>Acer saccharum</i>	55

With conclusions based on data from forests A, B, and D, it would seem that sweet gum and pin oak are the first to invade level, water-logged land. Pin oak shows greatest dominance with 56 of the 67 stems over five inches DBH. Later red maple, sour gum, cork elm, and shellbark hickory come in. In forest D surface drainage is better than in Forest A and the stand is more mature. Here pin oak has passed out completely, cork elm is very much

reduced in density, sweet gum, red maple, sour gum, and shellbark hickory are remaining but with a much reduced frequency on the part of the first three mentioned, inasmuch as white oak, certain ashes, and hickories, as well as beech, are just coming in along with the sugar maple. In forest B, a rather mature forest with good surface drainage, beech is clearly the dominant tree; however, sugar maple has by far the greater reproduction. Red maple and cork elm have disappeared, and white elm and tulip poplar have come in.

Discussion

Most investigators associated with the geographically delimited "flats" region of southeastern Indiana a beech-sweet gum forest cover. This is a generalized statement on plant sociology for a highly indefinite area as far as plant habitat is concerned. Quantitative field data are almost a necessity for a fairly accurate analysis of the conditions which control and the expression of forest which they induce. The best quantitative data were expected from an analysis of the combination study of frequency, density, and fidelity, especially to ascertain whether or not the more or less uniform Illinoian till plain region had a corresponding homogeneous forest cover; and for this reason these sociological concepts were stressed in the present study.

In a general way we might say beech-sweet gum make up much of the crown cover of the forests on the Illinoian till plain in southeastern Indiana; but micro-climate here imposes striking variations, too. As shown by Table IV, beech shows only a frequency index of 71.9 and sweet gum one of 55.6. In fidelity in appearance in the different forest stands (Table VII), beech shows only 88% and sweet gum 94%. That means that even in three stands or forests in this region beech and sweet gum were not present in the forest cover. In density (Tables I, II, VI) both of these two species are prominent in large size-classes, as well as in the younger growth. Beech with 1,421 stems and sweet gum with 1,506 stems in 16 stands considered control much of the crown cover.

It is at once quite evident, when considering the nine forests on the western lobe of the Illinoian till plain, that the habitat here must be strikingly different from that on the eastern lobe. Beech has a frequency of only 6.1% and sweet gum 9.5%. Density also drops into insignificance. Fidelity is a little higher than frequency, but both of the above named species are present only in less than one-third of the nine stands. This clearly shows that the two lobes are strikingly different as habitat sites. Gordon (1936) classifies the typical forest of this region (western lobe) as beech-sugar maple or beech-sugar maple-yellow poplar. The present study shows that all of these species are in the lowest frequency, density, and fidelity classes (Table VI) and thus play a secondary role in the crown cover of these forests. A study of Table VI will show that the forests are outstanding by heterogeneity, no few species controlling dominance over crown cover as in the forests on the eastern lobe. This at once indicates a heterogeneous habitat. In the highest frequency classes are *Ulmus racemosa* (45%), *Carya ovata* (53.9%), and several species of ash and oak with a F. I. in the lower twenties. Sugar maple has a F. I. of 15% and tulip poplar only 4.4%. With such low frequency,

fidelity, and density we would hardly be justified to consider them as key species typifying forest cover. *Carya ovata* has the greatest density of any species (407 stems), and *Ulmus racemosa* is second with a total of 341 stems (Table IX). These same two species have a 100% fidelity; *Quercus alba* has a fidelity of 88%. As a whole, the forests on the western lobe are more of the oak-hickory-elm type; but as previously stated, the region as a whole is marked by a heterogeneous crown control. So these two topographically similar regions are not in the least similar in plant cover.

There are, of course, various other comparisons that could be made between the forest complexes of these two regions, notably among them the fact that *Nyssa sylvatica* and *Acer rubrum* play an important part in the forests on the eastern lobe but are unimportant in forests on the western lobe, the tables on density, frequency, and fidelity showing these differences to full advantage. Note especially the summary presentation in Table IX.

Considering the 25 forests, we find that the only species with 100% fidelity is *Carya ovata* (Table VII); nearest this species is *Quercus alba* (84%), which indicates a greater potentiality for habitats in these species and suggests at the same time that the more localized dominants like beech, sugar maple, and sweet gum may represent more closely confined seral dominants in a succession cycle with optimum conditions pictured where density is high in both mature growth and reproduction. One of the environmental controls of this variation in forest type is indicated in the comparison of sites with and without gullying shown in Table VIII; but we must admit that, when considering the problem of plant sociology on the 25 sites of the Illinoian till plain in Indiana as a whole, we are confronted by a number of situations which are not easily explained by mere data from the vegetational complex. The habitats to all appearances are very much alike. Macroclimatic factors are similar for the whole season, and for this reason temperature and precipitation *per se* are probably not the primary cause of variation in forest types in these Illinoian till plain areas. The real cause must be sought for in edaphic factors. Soil texture, too, is rather uniform, and topography shows little variation; but the forest associations vary considerably on the different sites. Especially baffling is the distribution of beech. It may be a prominent dominant in water-logged sites as in forest F, associated there with sweet gum, sour gum, pin oak, and red maple, occupying the slightly elevated hummocks; or it may be co-dominant with sugar maple and white oak on well-drained mesophytic sites, as in forest B. This greater potentiality for habitat variation in beech was described by Potzger (1933) for the flood-plain and north-facing slopes of flanking uplands in the Salt Creek Valley in Monroe County, Indiana.

Pin oak and sweet gum are limited to wet sites, although sour gum and red maple have such a wide range of adaptability to habitat that they might be expected in any habitat, as Sampson (1930) also shows for northeastern Ohio.

The quantitative data collected during the present investigation do

not support entirely the classifications by a Committee of the Society of American Foresters (1932) and Weaver and Clements (1929), and they do not agree at all with the classifications by Gordon (1936) and Zon (1924).

As already pointed out, variation in forest association is especially marked on the western lobe, for no one species here shows a high per cent fidelity. Even though advantage of centers from which migration might take place can account for some heterogeneity in forest associations, it does not solve the whole problem, for time must eventually have modified such advantages. The real cause must be sought in hidden microclimatic differences in the habitat. If exposure of slope may initiate a sharp dividing line between beech-maple and oak-hickory in central Indiana, slight variations in edaphic or meteorological conditions may well account for the differences in the forests on the western lobe. This region is nearer the prairie influences so that the similarity in precipitation between the two lobes may well be eliminated by higher evaporation on the western lobe. Evaporation differences make beech-maple forests possible in northern Michigan with a rainfall of 25 inches and in Indiana with 40 to 45 inches. Rainfall in the uniform prairie formation ranges from 20 to 40 inches (Weaver and Clements, 1929). Yet in the end, evaporation difference unifies the effect on the plant cover.

Physiographic characteristics, such as the regional slope of the strata to the southwest and the proximity of the Wabash river drainage, might have developed better subsoil drainage in this western region than exists on the eastern lobe. Borings in Sullivan county disclosed sand and gravel in the lower layers of the soil and this would favor efficient subsoil drainage.

It appears that it is not the soil texture which exerts a selective influence on species and associations but rather the water relationship of the soil; and the associations will vary as sites vary in degree of drainage, approximating, thus, forest types controlled by physiography and topography in the unglaciated section of Indiana.

Taking the Illinoian till plain as a whole, there is no one species nor association of species which by their fidelity might be termed indicators of Illinoian till plain habitat sites. On the contrary, even though the two lobes are marked by topographic uniformity, vegetationally they present a series of habitat sites which range from late stages of a hydrosere to late stages of a xerosere. Results shown in Tables VIII and XI on frequency, density, and fidelity of the dominant species of the 16 forests on the eastern lobe indicate that pin oak, sweet gum, sour gum, cork elm, and red maple are early invaders of the level, poorly drained, undissected lands. As soon as hummocks raise the soil ten to twelve inches above the water table, beech, white oak, and shellbark hickory invade; and, with increasing drainage, sugar maple, tulip poplar, hickories, and oaks initiate the succession to a typical mixed mesophytic forest.

The forests on the western lobe can hardly be compared with those of the eastern lobe as to phytosociological complex unless they are con-

sidered an indication of succession from mesophytic to the drier site oak-hickory type of forest cover, for they are already expressions of such forest type.

Completing the indicated succession of the forests on the Illinoian till plain, we would have, beginning with undrained areas, invasion by pin oak, sweet gum, sour gum, cork elm, red maple to beech, white oak, and shellbark hickory, associated with the former species, to beech, maple, hickories, and mesophytic oaks, to typical oak-hickory dominance, initiated and maintained by degree of drainage of the soil. The shrub layer is poorly expressed in all stages of succession. Thus, when the vegetation of the Illinoian till plain as a whole is in question, all the various stages and forest types may be encountered.

Here, too, applies the statement by Nichols (1929) "It should be borne in mind that in attempting to classify the facts of nature, we are dealing with merging phenomena."

Summary and Conclusions

1. A phytosociological study was made of the woody species in 25 forests on the Illinoian till plain in Indiana. Sixteen of these were located on the eastern lobe and nine on the western lobe.

2. The topography of the sites ranged from a very level surface without much surface drainage to areas with good surface drainage.

3. Habitat sites on both lobes are very similar as to soil texture, temperature, and precipitation factors.

4. The fine texture of the whitish clay soil is conducive to water-logged conditions where drainage is poor.

5. Forest types differ markedly in the various sites, especially with respect to eastern and western lobes.

6. Beech and sweet gum are in low frequency and density classes on the western lobe.

7. Shellbark hickory is the only species with 100% fidelity in the 25 forest sites.

8. Controlling factor in the selection of forest type appeared to be degree of drainage of the soil.

9. Dominant species in the water-logged sites were pin oak, sweet gum, red maple, sour gum, cork elm, and beech.

10. Beech showed a wide range preference with respect to available water in the soil. It invaded the higher hummocks in wet sites and continued as dominant into mesophytic beech-maple sites.

11. Dominants on the mesophytic sites are sugar maple, tulip poplar, pignut hickory, red oak, and beech.

12. With continued dissection of the site, mixed hardwoods gave way to oak-hickory.

13. Forests on the western lobe were predominatingly of the oak-hickory elm type.

14. Species showing greatest fidelity on the eastern lobe were: shellbark hickory 100%, sour gum 100%, sweet gum 94%, beech 88%,

white oak 88%, red maple 81%, red oak 81%, cork elm 75%, black cherry 75%, black oak 66%.

16. Species with highest F.I. on the eastern lobe were: beech 71.9%, sweet gum 55.6%, sour gum 46.3%, red maple 43.8%, shellbark hickory 41.6%.

17. Species with highest F.I. on the western lobe were: shellbark hickory 53.9%, cork elm 45.5%, pin oak 26.6%.

18. It is suggested that less soil water, because of greater evaporation stresses and better subsoil drainage, may account for low frequency and fidelity of beech, sweet gum, and sugar maple in the forests on the western lobe, with resultant oak-hickory-elm control.

Acknowledgments

To the following individuals and groups I am especially indebted:—Dr. R. C. Friesner, for the suggestion of the problem and for his untiring assistance in collecting the field data and his many helpful suggestions; Dr. J. E. Potzger, under whose supervision this work was done, for his many helpful criticisms and suggestions, critical reading of the manuscript, and aid in the field; Dayton Swickard, Byron Moss, Robert Kent, and Matthew Harmon, undergraduate students of the Botany Department, Butler University, who assisted in the field work; the Indiana Academy of Science for financial aid in carrying out the field work.

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- (Note: Copies of all Mss. referred to in this paper are on file in the Botanical Library of Butler University, Indianapolis, Indiana.)

Plant Structure as Influenced by Soil Moisture

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Introduction

In planning culture methods for a study of the influence of differing quantities of soil moisture upon plant structure, a general review was undertaken of the moisture properties of several soils to be used. These moisture contents in order of decreasing magnitude are (1) water-logged condition, (2) maximum water-holding capacity, as defined by Hilgard (1914) for a column of soil one centimeter high, (3) water-holding capacity for columns of varying height, with four inches predominant, since this was the height to be used in plant cultures, (4) optimum moisture content (the lower limit of plasticity), (5) field capacity, (6) moisture equivalent, (7) permanent wilting percentage, (8) hygroscopic coefficient, and (9) moisture content of air-dry soil. These moisture values for fine (dune) sand, sandy loam, brown silt loam, and black clay loam are exhibited in Table I.

TABLE I.—Summary of Moisture Properties of Soils

	Fine Sand	Sandy Loam	Brown Silt Loam	Black Clay Loam
Water-logging Percentage	49.66	42.77	61.30	79.22
Hilgard (1 cm.) Water-holding Capacity	32.86	36.80	60.90	78.73
4-inch Water-holding Capacity	26.00	31.70	43.30	57.23
"Optimum Moisture Content"	20.24	25.60	39.80	52.91
Field Capacity	9.8	16.43	26.20	30.00
Moisture Equivalent	6.04	14.88	26.80	33.29
"Safe" value above Permanent Wilting Percentage	4.50	8.50	13.60	16.80
Provisional Permanent Wilting Percentage	2.70	6.64	11.96	14.86
Hygroscopic Coefficient	3.03	5.00	5.82	8.98
Moisture content of Air-dry Soil	0.66	1.42	2.80	7.24

Culture Experiments

On the basis of moisture values determined it is possible to establish a control method for plant cultures employing three ranges of moisture variation—wet, moist, and dry. The upper limit of the high moisture range should not exceed the water-holding capacity of a four-inch column or an excessive wetness will prevail in the bottom part of the four-inch depth of soil in each container. The upper limit of the low

moisture range should not be less than the field capacity, or, when water is added to replace that lost from the plants, the bottom soil will not receive any of the water added. The lower limit of the low moisture range must be a safe margin above the value of the permanent wilting percentage. Thus the upper limit of the wet range and the upper and lower limits of the dry range were the starting points. The moist range was spaced equally between the wet and dry. This was accomplished by dividing the interval between the upper limit of the wet and the upper limit of the dry into six equal parts. The upper two of the sixths represent the wet range; the next sixth is the gap between wet and moist ranges; the next two sixths represent the moist range; and the last sixth is the gap between moist and dry ranges. Thus, in each of the three ranges, the soil moisture, though it could not be held constant at a particular percentage, varied only within limits not widely separated, and the moisture values within any one range were at all times different from those in other ranges.

Zinnia (Red Riding Hood variety), *Phaseolus* (Stringless Green Pod variety), *Impatiens* (balsam), and *Ricinus* (castor bean) were selected for growth experiments. No. 2 tin cans which were paraffin-lined and tared to equal weight by drops of liquid paraffin were used throughout the experimental work. Cover lids punched with a central one-half inch hole were also tared to equal weight. The lids were not sealed nor the holes plugged with cotton; the lids thus retarded surface evaporation greatly but did not interfere with the diffusion of gases. This method of preparing the cans for planting is a modification of the method used by Veihmeyer and Hendrickson (1928) in their direct determination of permanent wilting.

Equal weights of an air-dry soil which had been passed through a one-sixteenth-inch mesh screen were placed in the plant containers. Packing was accomplished by dropping each container five times through a distance of three inches. Thirty cans were assigned to *Zinnia* (ten to each of the three moisture series), and fifteen to *Phaseolus*, *Impatiens*, and *Ricinus*, respectively.

On the basis of oven-dry weight of soil in each container the upper and lower moisture limits were calculated in grams, and water to bring the moisture content to the upper limit was added. By daily weighings and the addition of water at the top to bring to the upper limit when the lower limit was approached or reached, the range of soil moisture for each series was maintained. The alternate loss by transpiration and evaporation and replacement of water by addition at the top approximates field conditions of both watering (by rainfall) and the effect of watering upon the movement of gases in the soil. Furthermore, the wettest layers of soil are brought nearer the source of gaseous supply.

The pot cultures of the wet, moist, and dry series were kept on a large turn-table (to eliminate inequalities of lighting) in a greenhouse with temperature ranging usually between 65°-75° F. Above this turn-table were strong Mazda lamps to extend the winter hours of lighting in early morning and late afternoon.

From the time of expansion of the first leaves, leaf and internode measurements were followed in careful detail. The size and number of

flowers were recorded for all plants. Root distribution and abundance were studied in each moisture series.

Material for anatomical study was collected from roots, stems, and leaves. Measurements of tissue thickness and cell size were made with an ocular micrometer ruled in the form of a square.

Fresh and dry weights of both tops and roots were determined for the plants of each culture experiment.

The total amounts of water required by the pot cultures of each moisture series were calculated on the basis of the number of cubic centimeters of water necessary to bring each culture to the upper limit of the particular moisture range when the lower limit had been reached.

Summary of Significant Results

Culture methods involving watering at the top appear definitely superior to bottom watering methods, since in the former the influences of gravity, absorption, and evaporation all tend toward more nearly equable distribution of moisture throughout the soil mass.

All data upon the growth and distribution of roots and the form and size of shoot in the four plants studied indicate that there is an optimum moisture content for growth in soils. *Zinnia* exhibited best growth and development in the moist range, although approaching the lower values of this range in the finer-textured soils. Plants of *Impatiens* in the moist series were far superior to those in the other two series. *Phaseolus* showed a like response although here the optimum appeared to lie toward the upper limit of the moist range. The entire development of *Ricinus* was best in the wet range.

With the exception of *Ricinus*, the shoots exhibited a greater size than roots in all plants.

The fresh weight of the roots was greater in the moist series. The greatest loss of weight upon oven-drying likewise took place in roots of the moist series, thus giving the smallest proportion of dry-matter as an end result in the moist series of *Phaseolus* and *Ricinus*, but in the dry series of *Zinnia* and *Impatiens*.

In all instances the shoots showed an increase in weight over the roots. Both fresh and dry weights of *Zinnia*, *Phaseolus*, and *Impatiens* were greatest in the moist series, but in the wet series for *Ricinus*.

Number of flower heads and individual ray and disc flowers of *Zinnia* were greatest in the moist series. This was true also for number of flowers in *Impatiens*. However, in *Phaseolus* the number and size of flowers and fruits showed a distinct overlapping between moist and wet series. Branches, where present in any of the plants, were of greater number in the moist series.

Anatomical data from *Zinnia* indicated a greater diameter of stem in the moist and wet cultures but a greater size and number of xylem vessels and larger vascular bundles in the moist series. However, the bundles were more numerous and the strengthening tissue proportionately greater in the dry series.

The plants of the dry moisture range showed smaller and more compactly arranged cells, a second partially-developed palisade layer,

fewer air spaces, a better development of veins, a slightly thicker upper epidermis, and a higher stomatal frequency than plants of the other two series. These features of xerism are attributed solely to the soil moisture conditions, since the plants of all three moisture ranges were kept under the same atmosphere conditions.

The slightly larger number of chloroplasts constantly in evidence throughout the leaf sections of the moist-series plants, together with a greater leaf surface, would effectively indicate a greater photosynthetic surface.

The total water requirement of each plant studied was closely correlated with the developmental and structural response of that plant, thus lending greater emphasis to the conclusion that *Zinnia*, *Phaseolus*, *Impatiens*, and *Ricinus* have an optimum moisture range for growth.

The essence of the method of moisture control used in these experiments is the recognition that truly constant moisture values are neither possible nor desirable to maintain and that such a condition is practically never found in nature. It is possible, however, to restrict alternations in moisture content within controlled limits. Non-overlapping moisture ranges further enable one to produce an experimental contrast for testing the influence of different soil moisture values.

By this mode of soil-moisture control there is provided a means of exact comparison with soils of varying texture, since, after the required physical determinations of moisture properties have been made, the soil moisture ranges for one texture of soil can be calculated to be exactly equivalent to those for another texture.

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Myxomycetes of Clark County, Indiana, II

WILLIAM D. GRAY, Jeffersonville, Indiana

Several seasons of intensive collecting since the publication of the first list of Clark County myxomycetes (Gray, 1936), have brought to light numerous species not included in the first paper. Thirty-four species and varieties were listed in the former publication, and twenty-seven are included in this one, bringing the total to sixty-one—approximately one-seventh of the total number of known species, according to the Macbride and Martin interpretation (1934). It is recognized that in some cases the value of short local lists is subject to question; however, in the present instance, such lists seem to be justified in view of the fact that there is a marked paucity of literature relevant to the myxomycete flora of Indiana. This fact may be borne out by a systematic search through Macbride and Martin's work which reveals but one Indiana citation (p. 161). It is the hope of the writer eventually to extend this work until a more thorough survey of the state has been made, and, at present, collections from twenty-six counties are at hand.

Specimens are deposited, with the same numbers under which they are listed here, in the herbarium of DePauw University. Species marked with an asterisk are being reported for Indiana for the first time. Thanks are due Dr. G. W. Martin, State University of Iowa, and Mr. Robert Hagelstein, Honorary Curator of Myxomycetes, New York Botanical Garden, for the examination of doubtful specimens.

Arcyria nutans (Bull.) Grev.

A cosmopolitan species first collected in Clark County in 1936 but observed numerous times since. (Nos. 232, 257, 338, 344.)

**Badhamia decipiens* (Curtis) Berk.

Represented by one collection in which the sporangia have been rather severely attacked by a species of *Cephalosporium*. Since, however, there are no other reports of this species for Indiana, it seems worth while to mention this specimen in spite of its poor condition. The *Badhamias* are poorly represented in Indiana, reports of but two species having been made by earlier workers. (No. 328.)

Comatricha pulchella (Bab.) Rost.

A minute species, represented by only one collection. Probably frequently overlooked because of its small size. (No. 269.)

Cribraria dictydoides Cooke & Balf.

Listed by Macbride and Martin as the most common *Cribraria* in the Mississippi valley; collected but twice. Further search should reveal many more fruitings. (Nos. 286, 402.)

**Cribraria elegans* Berk. & Curt.

A delicate species, hitherto unreported for Indiana; represented by one small collection. The writer's specimen No. 306 is also this species

but is from Decatur County and as yet has not been reported. (No. 229.)

**Cribbraria intricata* Schrad.

Listed as a rare species and collected in the county but twice. Welch's collection from Fountain County, No. W5190, is also this species. (Nos. 381, 385.)

**Diderma effusum* (Schw.) Morgan

Olive (1898) reported var. *reticulatum* from Montgomery County, but there has been no report of the species itself from the state; it is generally listed as rare in America. (No. 256.)

**Diderma rugosum* (Rex) Machr.

A rare species reported from very few states; easily recognized by its wrinkled, areolate peridium and by the presence of a large columella. (No. 360.)

Diderma spumarioides Fries

A widely distributed species. (Nos. 363, 367, 393, 398.)

Diderma testaceum (Schrad.) Pers.

Not rare. Occurring generally on fallen leaves (particularly beech) but may also be found on small decayed twigs. (Nos. 342, 346, 349, 354, 362, 384, 387, 392.)

Enteridium rozeanum Wingate

Collected twice, but only once in the typical form. (Nos. 274, 275.)

Hemitrichia serpula (Scop.) Rost.

A species listed as being very common, but collected only once; easily overlooked because of its typical occurrence on the lower surface of decaying wood or fallen bark. (No. 337.)

Ophiotheca chrysosperma Currey

Commonly found on the lower surfaces of pieces of fallen bark; rather easily overlooked, particularly in sparse fruitings, because of the small size of the looped or U-shaped plasmodiocarps and the color of the peridium, which blends with that of the substratum; quite evident when the peridium is ruptured, exposing the bright yellow capillitium. (Nos. 372, 375, 381, 382, 385, 386, 389, 399.)

Physarella oblonga (Berk. & Curt.) Morg.

Very common on decayed logs and stumps, particularly in moist woods along the Ohio River; occurring in the plasmodiocarpous as well as the typical sporangiate form. (Nos. 215, 216, 221, 226, 247, 282, 287, 403.)

Physarum bivalve Pers.

Common on decaying leaves and small twigs and once observed on a low-lying branch of poison ivy. (Nos. 336, 339, 347, 357, 400, 401.)

**Physarum gyrosum* Rost.

Specimen No. 5 was erroneously reported as *P. cinereum* in the first list of Clark County myxomycetes, but has subsequently been determined as this species. This specimen occurred on living grass; two additional fruitings have been found on living moss. (Nos. 5, 356, 358.)

Physarum leucopus Link

Listed as a rare species; collected but once. (No. 327.)

Physarum melleum (Berk. & Br.) Massee

Represented by one collection. (No. 276.)

Physarum notabile Macbr.

This form is listed by Macbride and Martin as an eastern United States species. (No. 277.)

Physarum polycephalum Schw.

A very common species in other regions, but continued search in Clark County has revealed it but once. (No. 285.)

Physarum pusillum (Berk. & Curt.) Lister

A cosmopolitan species. (Nos. 208, 380.)

Physarum tenerum Rex

Occurring frequently in the Arctic Springs region, east of Jeffersonville, although listed as rare. An excellent species for culture work and laboratory demonstration. (Nos. 222, 284.)

Stemonitis herbatica Peck

Occurring on petioles and laminae of fallen leaves of oak and cottonwood; also collected on a living twig of poison ivy. (Nos. 250, 251, 252, 253.)

Trichia affinis deBary

Represented by one rather weathered collection. (No. 369.)

Trichia persimilis Karst.

Most frequently found under the bark of decaying logs, particularly those of wild cherry. Very abundant in early September, at which time it has been found frequently, both in the plasmodial and mature states, by peeling off the bark of moist, decayed wild cherry logs. In Wisconsin this species has been found on birch logs by the same procedure. (Nos. 235, 242.)

Tubifera ferruginosa (Batsch) Gmel.

Listed in taxonomic works as occurring throughout the northern hemisphere. (No. 206.)

Tubifera stipitata (Berk. & Rav.) Macbr.

Despite continued search for this interesting species, only four fruitings have been found. Apparently not common in Indiana but reported once before by Mutchler (1903) from Kosciusko County. (No. 268.)

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SECTION ON CHEMISTRY

Chairman: FRANK V. GRAHAM, Ball State Teachers College

During the greater part of the session of the Section on Chemistry, about 100 to 125 members of the Academy and students of Purdue University were in attendance. The papers which were given are published in full or represented by abstracts below. Professor Herman T. Briscoe, Indiana University, was elected chairman of the section for 1939.

ABSTRACTS

A striking illustration of periodicity among some of the halogens. FRANK B. WADE, Shortridge H. S., Indianapolis.—Solutions of iodine in aqueous solutions of KI, KBr, KCl, and KF show a series of colors ranging from the familiar deep brown of the iodine-iodide solution through a lighter brown for the iodine-bromide solution, a still lighter brown for the iodine-bromide solution, and a pale brown for the iodine-fluoride solution. These may be measured in a color comparator. A search of the literature is being made on the solubility of iodine in the various halide solutions, and the other halogens will be studied as to their solubility in halide salts. Values will be plotted against atomic numbers to show periodicity.

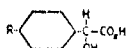
Movie demonstrations in quantitative analysis. M. G. MELLON, Purdue University.—In the usual demonstration of certain techniques in analysis only a few students can be accommodated at one time. The movie film makes such demonstrations easily visible to many. Two films have been prepared for such use. One shows the operations of using a balance to weigh samples, and the other shows the formation and handling of a precipitate which is to be weighed.

A protective coating for zinc surfaces. E. J. WILHELM, University of Notre Dame.—Zinc has excellent corrosion resistance, but under certain conditions involving contact with excessive moisture a bulky type corrosion product often forms. A protective film capable of preventing this corrosion is produced by immersion in an acid dichromate solution. Its effectiveness is attributed to the presence of a slightly soluble corrosion inhibitor which is released in the presence of water.

An Oxidation Method for the Proof of the Structure of Substituted Mandelic Acids

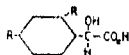
J. L. RIEBSOMER and HOWARD BURKETT, DePauw University

While preparing various substituted mandelic acids¹, it became necessary to find some method to prove the positions of the substituents on the benzene ring. For the simple cases such as



the problem was solved readily by oxidizing the mandelic acid derivative with excess alkaline potassium permanganate. In the case of the para alkyl-substituted mandelic acids this procedure produced terephthalic acid, the dimethyl ester of which is easily prepared and has a convenient melting point of 140°C.²

But when the problem is more complex in such a case as



it is not desirable to oxidize to the corresponding tricarboxylic acids, especially when small amounts are involved, because these carboxylic acids are relatively hard to purify, their melting points are high, and the melting points of the isomers are in some cases fairly close together. Hence, we sought a method by which it would be possible to oxidize the oxygenated side chain of the mandelic acids to a carboxyl group without effecting the alkyl groups. These alkyl-substituted benzoic acids are in general easy to purify and have satisfactory melting points for identification purposes.

The basis of the method devised to effect the above purpose is the relative ease with which the oxygenated side chain in these compounds is changed to a carboxyl group. It was found that, when a weighed amount of the mandelic acid was dissolved in dilute alkali and just sufficient potassium permanganate was added to oxidize the oxygenated side chain, the alkyl groups were not affected. The method has been applied to eight substituted mandelic acids to prove its general nature.

Although the use of potassium permanganate to oxidize alkyl benzenes is well known, a careful search of the literature failed to reveal an application to this case.

Experimental

Inasmuch as the procedure was the same in each case, only one example will be described in detail. One gram of 2,4-dimethyl mandelic

¹ Riebsomer, Irvine, and Andrews, 1938. *Proc. Indiana Acad. Sci.*, 47, 139.

² Riebsomer, Irvine, and Andrews, 1938. *Journ. Amer. Chem. Soc.*, 60, 1015.

³ Mulliken, 1914. *Identification of pure organic compounds*. 1, 85. John Wiley, New York.

acid was placed in 125 cc. of water, and 4 cc. of 10% sodium hydroxide was added. This mixture was warmed on a steam bath, and 0.59 g. of potassium permanganate dissolved in 40 cc. of water was added dropwise until the addition of a few drops of the permanganate solution left the solution permanently pink. The reaction proceeded very rapidly. This required practically all the 0.59 g. of permanganate. The excess of permanganate was destroyed with a few drops of sodium bisulphite solution, the manganese dioxide filtered, and the filtrate acidified with hydrochloric acid. A white precipitate formed, which upon crystallization melted at 126-126.5°C., which is the melting point of 2,4-dimethyl benzoic acid.

Table I presents a summary of the data, including the mandelic acids oxidized, the melting points of the oxidation products, and the melting points of the corresponding benzoic acids as reported in the literature.

TABLE I.

Mandelic Acid oxidized	M.p. of Oxidation product °C	Benzoic Acids	M.p. of benzoic acids—reported in literature °C
p-Methyl	176-177	p-Methyl	178-179
p-Ethyl	112-113	p-Ethyl	112-113
p-n-Propyl	141-142	p-n-Propyl	140-141
p-t Butyl	162.5-164	p-t-Butyl	164
p-t-Amyl	158-158.5	p-t-Amyl	158
2,4, Dimethyl	126-126.5	2,4, Dimethyl	126-127
2,5, Dimethyl	131.5-132	2,5, Dimethyl	132
3,4, Dimethyl	163.5-164	3,4, Dimethyl	163

The authors are glad to acknowledge that a part of this work is the result of a grant made to our Department of Chemistry through its head, Dr. W. M. Blanchard, by the Indiana Academy of Science, at its meeting in the spring of 1938.

Summary

An oxidation method to prove the structures of substituted mandelic acids has been presented and eight examples given.

Chemiluminescent Decomposition Products of Citric Acid

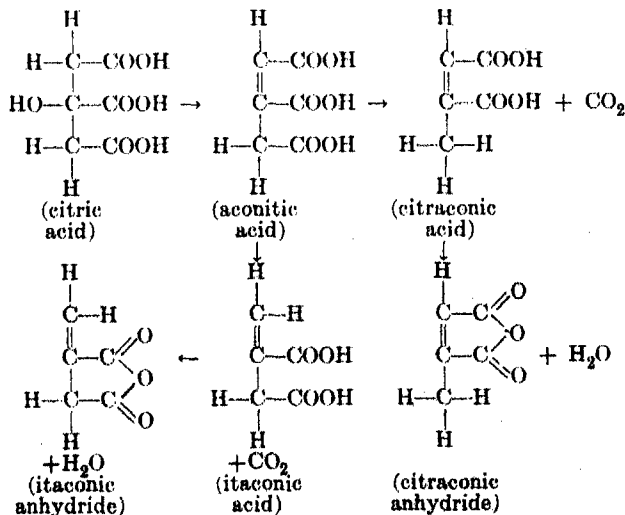
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The Cottman Laboratory of Photochemical Research, Madison

Introduction

There are a number of compounds which are not chemiluminescent themselves, but which, upon fusion and at high temperatures, yield decomposition products which are chemiluminescent upon oxidation. Among these may be mentioned glucose, sucrose, levulose, lactose, tartaric acid, galactose, malic acid, lactic acid, dextrin, potato starch, gum arabic, allantoin, alloxan, uracil, creatine, and citric acid. The citric acid yielded decomposition products which far surpassed all the others in the brilliance of their chemiluminescence. The writers have therefore attempted the separation and isolation of the various decomposition products of citric acid and have studied their chemiluminescent properties.

Discussion

Citric acid breaks down at 105°-120° to form aconitic acid, which in turn breaks down to produce citraconic acid, citraconic anhydride, itaconic acid, and itaconic anhydride. Using a supply of C. P. citric acid and following the method described by Shriner, Ford, and Roll¹, the writers succeeded in isolating all of the above compounds with the exception of the aconitic acid. There remained in the distillation flask, after driving off the above products, a dark brown residue of unknown composition. The reaction may be represented thus:



¹ Shriner, Ford, and Roll. *Organic syntheses*, 2, 23.

Melting points and boiling points of these products were determined as shown in Table I.

TABLE I.

Name	Melting Point	Boiling Point
Citraconic acid.....	68°-69°*	.....
Citraconic anhydride.....	10°	83° at 7 mm pressure
Itaconic acid.....	157°	.....
Itaconic anhydride.....	69°-72°	95°-100° at 1 cm pressure

*This one melting point seems to be quite out of line with the accepted values. However, we note a considerable discrepancy between authorities. Organic Syntheses records this melting point as 92°-93°; Kamm and the Handbook of Chemistry and Physics place it at 80°.

Of the above list of compounds which were isolated, citraconic anhydride was the only one which exhibited chemiluminescence. This luminescence was much brighter in dilute solution than in those of greater concentration, the optimum being at about 0.11 M. Either alcohol or acetone may be used as the solvent. The oxidizing agents used in this work were a combination of sodium hypochlorite and hydrogen peroxide in alkaline solution. This procedure has been described in a previous article².

The dark brown residue which remains in the distilling flask after the decomposition reaction is soluble both in alcohol and water, producing a brown solution. This is strongly luminescent when oxidized. It undoubtedly contains some complex condensation product which is responsible for this action. An attempt was made to remove the brown color from the solution by filtering it with animal charcoal. The color was adsorbed, but with it was removed the light giving substance also.

Summary

1. When citric acid is fused and heated to a high temperature, decomposition products result which are strongly chemiluminescent when properly oxidized.
2. Several of these decomposition products were isolated and tested for chemiluminescence.
3. Citraconic anhydride was found to be luminescent, optimum results being obtained from a 0.11 M solution.
4. Other light-giving substances of unknown composition are present in the dark brown residue from the citric acid decomposition.

² Cottman, Moffett, and Moffett, 1938. Proc. Indiana Acad. Sci., 47, 124-129.

Adsorption of Pancreatic Enzymes¹

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One of the first experiments on the adsorption of enzymes is described by Vogel (1). In these experiments, an albuminous precipitate was produced by the addition of lead acetate to a solution of pepsin. The precipitate possessed the property of adsorbing pepsin, which could be removed by treatment with hydrogen sulfide and water. The adsorption of pepsin by small particles of calcium phosphate, sulphur, and cholesterol is reported by Burke (2). The separation of the three enzymes of the pancreatic juice has been effected by adsorption methods of Danilewsky (3). In a similar manner, Cohnheim (4) has studied the adsorption of salivary and pancreatic amylase.

Adsorption technique in the separation of enzymes gained considerable impetus through the investigations of Michaelis (5) and Michaelis and Ehrenreich (6), in which adsorbents possessing charges opposite to those of the adsorbates were employed. The adsorption of the enzymes was therefore regarded as a result of the opposite electrical charges of the adsorbate and the adsorbent. Thus it was established "that all substances adsorbable by kaolin must be bases, and all substances adsorbable by alumina must be acids." This conception afforded a criterion for the separation of the enzymes mentioned on the basis of their electrochemical natures (7). Willstätter (8) states that these results apply only to crude enzyme solutions which contain varying amounts of foreign substances. From this investigation and others (9, 10), Willstätter concludes that the nature of the charge of the adsorbent does not necessarily define the nature of the enzyme which is adsorbed, but that the nature of the foreign substance accompanying the enzyme is a controlling factor in the adsorption of specific enzymes by certain adsorbents. Accordingly, an enzyme is considered to consist of an active catalyst and an inert carrier which is colloidal in nature. The carrier is considered to be a substance of high molecular weight, a protein or carbohydrate, and can be separated from the active enzyme and be replaced by another suitable carrier. This so-called carrier theory of the behavior of enzymes with respect to their separation by adsorption methods is substantiated by investigations reported by Fodor (11). According to recent investigations by Dyckerhof and Tawes (12) and Waldschmidt-Leitz and Kofranyl (13), the carrier of pepsin can be replaced by other proteins. Tauber and Kleiner (14), however, point out that the protein carrier of rennin cannot be exchanged for another. Northrup (15) and Sumner (16) show that the decrease in peptic activity is determined by the adsorption of pepsin protein.

¹ This paper is constructed from a dissertation by James Henry Young to the faculty of the Graduate School of Indiana University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Chemistry.

The protein nature of enzymes has been indicated by the work of Tauber and Kleiner (18, 19), in which it was found that rennin was digested with trypsin and pepsin, pepsin with trypsin, trypsin with pepsin, and salivary amylase with trypsin and papain. It was also found by Falk (20) that lipase is digested with trypsin.

The hydrogen-ion activity of the solution of the enzyme substrate affects the adsorption of the enzyme. It is found that the most efficient adsorption, with the least destruction of the enzyme, is at a specific pH value for each enzyme. The factors upon which the pH optimum depends are: the nature of the enzyme preparation, the rate of hydrolysis of the enzyme (21), the nature of the buffer employed to regulate the pH, and the nature of the substrate. The optimum pH for the digestion of olive oil substrate with lipase in the presence of ammonia-ammonium chloride buffer is 9.2, and for the digestion of trybutyrin substrate with lipase under the same conditions it is 8.3 (22). According to Kunitz and Northrop (23), the optimum for digestion of casein with purified trypsin is 8 to 9, while crude trypsin will digest casein at a pH of about 7.8. The pH for the adsorption of pancreatic amylase is optimum at about 7.2 (24).

In an effort to isolate a pure enzyme, Willstätter and his associates (25) succeeded in preparing very active concentrates of enzymes brought about by preferential adsorption followed by elution to free the adsorbed enzyme from the adsorbent. The maximum adsorption generally occurred at a definite hydrogen-ion activity and the most efficient elution at another. By this technique, these investigators succeeded in splitting some enzyme complexes into their components.

The purpose of this investigation was to study the adsorption of the enzymes, lipase, trypsin, and amylase, from solutions prepared from desiccated pancreatic extract. From these studies it was possible to prescribe an adsorption treatment for this mixture so that any two of the enzymes could be removed by adsorption on certain adsorbents, leaving any one of the enzymes in the "mother liquor" free from the other two. The behavior of the enzyme so isolated was then studied and compared with its behavior before treatment, that is, in the presence of the other two enzymes.

Proper adjustment of this pH, temperature control, and the use of solutions of bile salts in the digestion mixture were employed to furnish a more nearly natural environment.

Experimental

Materials.—The source of enzymes was desiccated pancreatic extract which contained the three enzymes, lipase, trypsin, and amylase. Pancreatic extracts were the Triple Strength Pancreatin furnished through the courtesy of the Eli Lilly and Company of Indianapolis and Armour and Company of Chicago. Both of these materials gave comparable results.

The adsorbents and their sources or methods of preparation were as follows:

Aluminum oxide on asbestos support was prepared by adding 250 ml. of 3 molar ammonium hydroxide to 250 ml. of aluminum sulfate in the presence of 10 g. of asbestos fiber. The hydrous aluminum oxide was thus precipitated on the asbestos fiber. This mass was dried at 100°C. and activated at 200°C. for 24 hours.

Hydrous aluminum oxide gel was prepared in the same manner as the above, but in the absence of the asbestos fiber. The gel was dried and activated at 250°C.

Lloyd's Reagent was obtained from E. H. Sargent and Company of Chicago, Illinois.

Animal charcoal was purchased from Diagger and Company, Chicago, Illinois.

Silica gel was grade 150-F-1000-3060, obtained from the Davison Chemical Corporation, Silica Gel Division, Baltimore, Maryland.

Cholesterol was obtained from the Pfanstiehl Chemical Company, Waukegan, Illinois.

Carborundum was supplied by the Carbon and Carbide Corporation, Niagara Falls, New York.

Permutite was purchased from the Chicago Apparatus Company, Chicago, Illinois.

Bone charcoal was purchased from the Diagger and Company, Chicago, Illinois.

Magnesium silicate was made by diluting sodium silicate with distilled water to a specific gravity of 1.06 and adding a molar solution of magnesium chloride to the silicate as long as the precipitation occurred. The precipitate was washed free of chlorides, dried in an oven at 100°C., and activated at 200°C. for 24 hours.

Graphite, the fine flaky grade, was purchased from the Chicago Apparatus Company, Chicago, Illinois.

Clay (bauxite) was prepared by activating bauxite at 200°C. for 24 hours. The bauxite was obtained from the Chicago Apparatus Company, Chicago, Illinois.

Kaolin (colloidal) was obtained from Merck and Company, Rahway, New Jersey.

Palladium black was bought from E. H. Sargent and Company, Chicago, Illinois.

The *egg albumen* used was an imported product from China.

Coconut charcoal was obtained from Eimer and Amend Company, New York.

Ferric oxide was obtained from the Chicago Apparatus Company, Chicago, Illinois.

Activated alumina was grade A., 14-20 mesh from the Alcoa Ore Company, East St. Louis, Illinois.

Blood charcoal was bought from Diagger and Company, Chicago, Illinois.

Pumice stone was prepared by treating with concentrated hydrochloric acid, washing with water, and activating for 4 hours at 250°C.

Hydrous aluminum oxide gel in alcohol was prepared in the same manner as the hydrous aluminum oxide gel mentioned above. Alcohol was added at the time of adsorption.

Procedure.—The technique for the adsorption of the enzymes was as follows: Ten grams of the triple strength pancreatin was suspended in 500 ml. of distilled water, to which had been added sodium carbonate and hydrochloric acid to produce a pH of 7.4. The mixture was allowed to stand for 12 hours and then centrifuged for 20 minutes at 2,000 r.p.m. To 100 ml. of the solution after centrifugation was added 10 g. of an adsorbent and the mixture was incubated at 37°C. for 24 hours. The mixture was then centrifuged for 20 minutes at 2,000 r.p.m., and the clear solution was used for determining the enzyme or enzymes that were removed by the adsorbent. A negative test for an enzyme in this clear solution was taken as the indication that it had been removed by the adsorbent.

Tests for lipase were made with olive oil as the substrate in the following manner: To 2 ml. of olive oil was added 15 ml. of the solution after treatment with the adsorbent and the mixture adjusted to a pH of 8 and incubated at 37°C. for 24 hours. The presence of lipolytic activity was indicated by the production of fatty acids as measured by 0.1 N. potassium hydroxide solution required to adjust the pH back to 8.

The presence of amylase in the enzyme solutions after treatment with the adsorbents was detected with the use of starch as the substrate. Five ml. of the solution was added to 10 ml. of a 1% starch solution, and the mixture was adjusted to a pH of 7.2 and incubated at 37°C. for 24 hours. Amylase activity was indicated by tests with iodine, fuchsin, and Fehling's solution which detected the presence or absence of hydrolytic products of the starch.

A solution of casein in normal sodium acetate solution was used as the substrate in the detection of trypsin. Two ml. of the enzyme solution, after treatment with the adsorbents, was added to 10 ml. of the casein solution and the mixture adjusted to a pH of 8 and incubated at 37°C. for 6 hours. The absence of trypsin in the solution was indicated by the production of a white precipitate upon the addition of a few drops of acetic acid.

In order to improve the tests for the three enzymes in the solutions, a few drops of bile salt were added to the digestion mixtures. The bile salt produced a more natural environment for the enzymes and, as a result, increased their respective activities. This proved especially valuable in the lipase tests.

Data and Results.—The data in Table I show the adsorption of the enzymes by the various adsorbents studied. The enzyme adsorbed is indicated by the minus sign (—); which indicates that the enzyme was not present in the solution remaining after treatment with the adsorbent. A positive sign (+) signifies the presence of hydrolytic products in the substrate and indicates that the enzyme was not removed by treatment with the adsorbent.

In general, it is noticed that the aluminum-containing adsorbents manifest a selective adsorptive capacity for lipase and trypsin. Likewise, the silica containing adsorbents and egg albumen, blood charcoal, and bone charcoal seem to adsorb amylase preferentially.

In Table II the adsorbents are listed according to their abilities to adsorb each of the three enzymes studied. From the table it may be seen that lipase and trypsin are adsorbed by the aluminum- and the silica-bearing compounds more readily than by any of the other adsorbents. Amylase is best adsorbed by the charcoals and egg albumen.

By virtue of the selective adsorption of the enzymes in pancreatin by the adsorbents studied, it is possible to choose certain adsorbents and devise a technique by means of which a complete separation of the three enzymes may be effected. By this means, the mixture of the three enzymes may be treated in such a manner that the solution remaining after treatment will contain only one of the active enzymes.

TABLE I.—Removal of Enzymes from Pancreatin with Various Adsorbents

Adsorbent	Enzymes		
	Lipase	Trypsin	Amylase
Al(OH) ₃ gel in alcohol	—	—	+
Al(OH) ₃ gel	—	—	+
Al ₂ O ₃ on asbestos	—	—	+
Activated alumina	—	—	+
Bauxite	—	—	+
Kaolin	—	—	+
Silica gel	—	+	+
Lloyd's Reagent	—	—	+
Magnesium silicate	+	—	—
Permutite	+	—	+
Soapstone	—	+	—
Carborundum	+	—	+
Pumice	+	—	+
Palladium black	—	+	+
Animal charcoal	—	+	+
Blood charcoal	—	+	—
Bone charcoal	—	+	—
Cocoonut charcoal	—	+	+
Graphite	—	+	+
Cholesterol	—	+	+
Egg albumin	+	—	+

+, presence of the enzyme after the mixture has been treated with the adsorbent.

—, absence of the enzyme after the mixture has been treated with the adsorbent.

TABLE II.—The Adsorbents Which Adsorb Each Enzyme

Enzyme Adsorbed	Adsorbent
Lipase*	Al(OH) ₃ gel in alcohol
	Al(OH) ₃ gel
	Al ₂ O ₃ on asbestos
	Activated alumina
	Bauxite
	Kaolin
	Silica gel
	Lloyd's Reagent
	Soapstone
	Palladium black
	Animal charcoal
	Blood charcoal
	Bone charcoal
	Cocoonut charcoal
	Graphite
	Cholesterol
Trypsin	Al(OH) ₃ gel in alcohol
	Al(OH) ₃ gel
	Al ₂ O ₃ on asbestos
	Activated alumina
	Bauxite
	Kaolin
	Lloyd's Reagent
	Magnesium silicate
Amylase	Permutite
	Carborundum
	Pumice
	Magnesium silicate
	Soapstone
	Blood charcoal
	Bone charcoal
	Egg albumin

*No assay showing the quantity of lipase present in the triple strength pancreatin was available. The experiments of this investigation indicated a low content of lipase which probably accounts for the fact that so many adsorbents were found to leave the mixture free from lipase.

Table III indicates the conditions required to carry out this concentration of a single enzyme. In some instances the first treatment with a given adsorbent will remove one of the enzymes and only part of the second, which makes it necessary to treat the solution a second time with the same adsorbent to remove completely the second enzyme and produce a solution containing only one enzyme.

TABLE III.—Adsorption Technique which, when Applied to Pancreatin, Will Remove All but One of the Enzymes, Lipase, Trypsin, or Amylase

ADSORPTION METHOD LEAVING LIPASE IN SOLUTION (pH = 6-7.6)

Adsorbent	Enzyme removed	Enzyme remaining
1. Mg-silicate 2. Mg-silicate	trypsin, some amylase amylase	some amylase, lipase lipase
1. Permutite 2. Mg-silicate	trypsin amylase	amylase, lipase lipase

ADSORPTION METHOD LEAVING TRYPSIN IN SOLUTION (pH = 6-7.6)

Adsorbent	Enzyme removed	Enzyme remaining
1. Soapstone 2. Soapstone	lipase, some amylase amylase	some amylase, trypsin trypsin
1. Soapstone 2. Egg albumin	lipase, some amylase amylase	some amylase, trypsin trypsin
1. Coconut charcoal 2. Egg albumin	lipase amylase	amylase, trypsin trypsin
1. Coconut charcoal 2. Bone charcoal	lipase amylase	amylase, trypsin trypsin
1. Blood charcoal 2. Blood charcoal	lipase, some amylase amylase	some amylase, trypsin trypsin

ADSORPTION METHOD LEAVING AMYLASE IN SOLUTION (pH = 6-7.6)

Adsorbent	Enzyme removed	Enzyme remaining
1. Al_2O_3 on asbestos 2. Al_2O_3 on asbestos	lipase, some trypsin trypsin	some trypsin, amylase amylase
1. Bauxite 2. Bauxite	lipase, some trypsin trypsin	some trypsin, amylase amylase
1. $\text{Al}(\text{OH})_3$ gel 2. Permutite	lipase, some trypsin trypsin	some trypsin, amylase amylase

TABLE IV.—Activity of Enzymes of the Pancreatic Mixture Compared with Their Activities after Isolation by means of Adsorption from the Other Enzymes

enzyme	in presence of	in absence of	substrate	enzyme solution (ml)	enzyme potency
Lipase	trypsin amylase		2 ml. olive oil	15	8.5 ml. 0.1 N KOH to neutralize fatty acid after 2 hours digestion
Lipase		trypsin amylase	2 ml. olive oil	15	14.2 ml. 0.1 N KOH to neutralize fatty acid after digestion for 2 hours
Trypsin	lipase amylase		10 ml. case in solution	2	complete digestion in 5 minutes
Trypsin		lipase amylase	10 ml. case in solution	2 2	complete digestion in 1 minute
Amylase	lipase trypsin		10 ml. starch paste	5	complete digestion in 4 minutes
Amylase		lipase trypsin	10 ml. starch paste	5	complete digestion in 0.5 minute

This difficulty may be eliminated by using double the weight of the adsorbent per unit volume of the enzyme solution.

In all instances it was found that the activity of the single enzyme remaining after the treatment of the mixture of the three with the suitable adsorption technique was greater than when it was present in the original mixture of the three enzymes. The data in Table IV indicate the activity of each of the enzymes, lipase, trypsin, and amylase, in the solutions treated with the suitable adsorbents as compared with the activity of the enzymes in the presence of the other two.

Summary

1. The following materials are reported as new adsorbents for certain enzymes: soapstone for lipase and amylase; bauxite for lipase and trypsin; graphite for lipase; carborundum for trypsin; and magnesium silicate for trypsin and amylase.

2. From studies involving adsorption of the enzymes, lipase, amylase, and trypsin, which occur in desiccated pancreatin, it was possible to develop adsorption technique by means of which any two of the enzymes may be removed from the third.

3. The potency of the enzyme thus isolated was found to be much greater than when the enzyme was in the presence of the other two.

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The Preparation of Acetyl Bromide from Acetic Acid and Bromine in the Presence of Red and Yellow Phosphorus

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The use of red phosphorus in the bromination of aliphatic acids is not new. Gal¹ and Hanriot² used this method for the preparation of acetyl bromide. Various later workers have used red phosphorus either in catalytic or molar quantities for the preparation of acid bromides, alpha-bromo acids, or alpha-bromo acid bromides.

It was stated by Hell³ that the presence of small amounts of phosphorus resulted in large amounts of acetyl bromide whereas molar amounts tended to yield mainly bromoacetyl bromide. The mechanism of the reaction as postulated by Zelinsky⁴ and Volhard⁵ was the complete conversion to the acid bromide followed by alpha bromination. This explanation was abandoned by Hell³ since it was found that alpha-bromination could occur with catalytic quantities of phosphorus. Later experiments by Ward⁶ confirm the earlier conclusion that large quantities of phosphorus favor acid bromide formation.

The yields obtained by the use of bromine and red phosphorus for the preparation of acetyl bromide from glacial acetic are illustrated in Table I.

TABLE I. Illustrative Yields Obtained by the Use of Red Phosphorus and Bromine on Glacial Acetic Acid

No.	Gm. Br.	Gm. p (red)	Gm. AcOH	Temp.	Time	% Yield	Remarks
1*	80	10	60	85	2	12	Stood 24 hours.
2*	100	10	60	95	1	8	Refluxed.
3*	180	4	30	?	?	10	Method of Hanriot.
4	240	33	90	?	?	47	Reported by Gal.**
5†	100	13.7	37.4	?	2½	23	Method of Gal.
6†	100	13.7	37.4	?	2½	38	Method of Gal.
7†	100	13.7	37.4	?	2½	36	Method of Gal.

* Experiment carried out by author.

† Experiment carried by D. Herman on NYA assignment.

** Gal, 1863. *Annalen* 129, 53.

The successful use of a mixture of red and yellow phosphorus for the preparation of ethyl bromide from ethyl alcohol and bromine⁷

¹ Gal, 1863. *Annalen* 129, 53.

² Hanriot. *Ann. Chimie et Physique* (5) 17, 83.

³ Hell, 1881. *Berichte* 14, 591.

⁴ Zelinsky, 1887. *Berichte* 20, 2026.

⁵ Volhard, 1888. *Annalen* 242, 141.

⁶ Hell, 1888. *Berichte* 21, 1726.

⁷ Ward, 1922. *Journ. Chem. Soc.* 121, 1161.

⁸ Degering, Ed. F., and Goshorn, R. H., 1926. *Proc. Indiana Acad. Sci.* 45, 139-144.

suggested the use of a similar mixture for the preparation of acetyl bromide.

Glacial acetic acid was treated with bromine in the presence of varying amounts of red and yellow phosphorus and under differing experimental conditions. The data on these experiments are recorded in Table II.

TABLE II.—Summary of Experiments Conducted Using a Mixture of Red and Yellow Phosphorus

No.	Gm.Br	Gm.P		Gm.AcOH	Temp. °C.	Time	% Yield	Remarks
		red	yellow					
1	80	5	5	60	below 45	1½	35	Stood 22 hrs. after Br addition.
2	85	5	7	60	15-30	1½	41	Stood 22 hrs. after Br addition.
3	45	2	4	30	below 25	1½	57	Stood 48 hrs. after Br addition.
4	85	5	6½	60	10-20	3½	64	1st heated to 90°, Br dropped in.
5	80	5	5	60	below 30	1	52	Dist. at once.
6	160	4	5	60	10-20	3½	32	Br dropped in.
7	100	3	5	60	20-40	2	52	Dist. at once, excess Br.
8	100	2	7	60	30-45	3½	49	P didn't all react.
9	100	3	6	60	20-40	3½	49	1st heated to 45°.
10	100	4	5	60	60-80	2	37	No external cooling.
11	80	4	5	60	40-45	2½	53	Refluxed till Br reacted.
12	100	4	5	60	35-50	1½	63	Refluxed till Br reacted.
13	100	4	5	60	35-45	1	65	Refluxed till Br reacted, (70°).
14	100	4	5	60	150-170	½	59	Refluxed till Br reacted.
15	100	4	5	60	175-190	½	27	Refluxed till Br reacted.

*% Yields are based on the amount of bromine used assuming the following equation to be correct:
 $4\text{CH}_3\text{CO}_2\text{H} + \text{P} + 2\frac{1}{2}\text{Br}_2 = 4\text{CH}_3\text{COBr} + \text{PO}(\text{OH})_3 + \text{HBr}.$

The following procedure was adopted: Place 60 g. of glacial acetic acid, 5 g. of yellow phosphorus, and 4 g. of red phosphorus in a 250 ml. round-bottom flask. Fit the flask with a thermometer, a reflux condenser and a dropping funnel, the tip of which must extend below the surface of the liquid in the flask. Place 100 g. of bromine in the dropping funnel and introduce it into the reaction mixture at such a rate as to require approximately one hour for the addition. Maintain the temperature at 35-50°C. by occasional shaking and external cooling if necessary. After the addition of bromine is complete, reflux the reaction mixture until the red color due to bromine disappears.

Substitute a Liebig condenser (set for distillation) for the reflux condenser and distil the mixture under anhydrous conditions, collecting everything which comes over below 130°. Redistil the distillate so obtained through a Vigreux or similar column, making sure that anhydrous conditions obtain. Collect the fraction boiling 74-80°. Yield is 78-80 g., 63-65% of the theoretical.

Summary

1. Experiments were conducted for the preparation of acetyl bromide from glacial acetic acid and bromine in the presence of a mixture of red and yellow phosphorus.

2. A procedure was developed which gives a 63-65% yield as compared with a reported 47% yield obtained by the use of red phosphorus alone.

A Study of the Preparation of the Lower Alkyl Iodides

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The present study of the lower alkyl iodides was undertaken when a literature survey revealed disagreement in the ratio of chemicals, procedure, purification, and storage of these compounds'. While the majority of laboratory manuals recommend the use of red phosphorus,

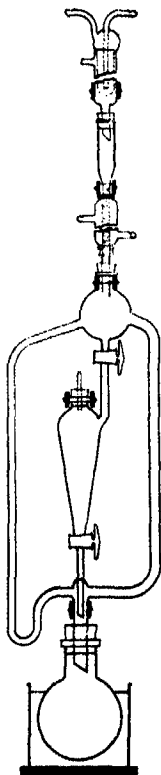


Fig. 1.

iodine, and the proper alcohol, *Organic Syntheses* recommends equal amounts of red and yellow phosphorus, iodine, and the proper alcohol². A series of experiments was conducted to determine the effect of the ratio of red to yellow phosphorus upon the yield of the iodide. Ethyl iodide was prepared in these experiments and the results are indicated in Table I³.

¹ Data collected from laboratory manuals by R. F. Duncan of Purdue University.

² *Organic Syntheses*. 13, 61.

³ The experimental data listed in this table were obtained by B. J. Freedman under an NYA assignment.

TABLE I.

Run No.	Iodine g.	Alcohol ml.	Phosphorus		Iodide %
			red	yellow	
1	75	90	7.50	0.00	86.5
2	75	90	7.50	0.00	86.0
3	75	90	7.50	0.00	87.0
4	75	90	6.25	1.25	88.1
5	75	90	6.00	1.50	88.7
6	75	90	6.00	1.50	88.3
7	75	90	3.75	3.75	89.5
8	75	90	3.75	3.75	88.2
9	75	90	3.75	3.75	88.8
10	75	90	1.50	6.00	90.2
11	75	90	1.50	6.00	88.0
12	75	90	1.50	6.00	88.5
13	75	90	0.00	7.50	91.0
14	75	90	0.00	7.50	90.5
15	75	90	0.00	7.50	90.0

The results in Table I indicate that the yields of iodide are increased when yellow phosphorus is introduced into the reaction, but these increases do not justify the hazard encountered in handling yellow phosphorus. Furthermore, red phosphorus reacts less violently, and a more controllable reaction ensues.

The apparatus used is a modified type of that recommended in *Organic Syntheses* as indicated in Figure 1. Five hundred fifty milliliters of the absolute alcohol is poured into the reaction flask. This flask is then charged with 50 g. of red phosphorus per pound of iodine to be added. The reaction flask is attached to the apparatus as indicated in Figure 1 and heated with an oil bath until the apparatus is operating under full reflux. The bath temperatures for the respective iodides may be found in Table II. Meanwhile, 100 ml. of the absolute alcohol, followed with 25 g. of iodine, is added to the dropping funnel. When full reflux is attained, the solution in the dropping funnel is introduced dropwise into the reaction flask, and the condensed liquid is allowed to flow into the dropping funnel. As soon as the solution in the dropping funnel is clear or nearly so, another 25 g. of iodine

TABLE II.

Iodide	Boiling Point °C.	Boiling Point of alcohol °C.	Bath Temperature	Addition rate of I ₂ min./lb.
Methyl	42.5	64.6	105	62
Ethyl	72.2	78.5	130	62
Isopropyl	89.5	82.5	130-5	63
n-Propyl	102.4	97.2	150-60	61
n-Butyl	131.0	117.7	180-200	70

is placed in the funnel. The average time of addition for the first pound of iodine is listed in Table II. The addition rate is constant above one pound of iodine. (The apparatus is designed to use three pounds of iodine.) The contents of the reaction flask are allowed to reflux until the condensed liquid becomes colorless.

The contents of the reaction flask are distilled from the flask directly into ice water, and the iodide and alcohol are separated by selective solution. Data for this separation may be found in Table III. The iodide is washed several times with water and stored in amber bottles over anhydrous calcium chloride.

TABLE III.

Iodide	Solubility in Water		Yield %
	Iodide	Alcohol	
Methyl	1.4	∞	90
Ethyl	0.4	∞	90-5
Isopropyl	i	∞	95
n-Propyl	i	∞	90-5
n-Butyl	i	8.3	90-5

i = insoluble

Summary

The use of red phosphorus is conducive to a smooth reaction and eliminates the hazards encountered in handling yellow phosphorus. The procedure and apparatus recommended present the advantages gained in handling smaller quantities of reagents, permitting the condensed liquids to return to the reaction flask without encountering the ascending vapors and allowing the iodine to be added more rapidly and in smaller quantities.

The Bromination of Acetone in Non-Aqueous Solutions

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The autocatalytic reaction of acetone with bromine and iodine in non-aqueous solutions has been studied by Dawson¹, by Watson², and by Cohen³. Preparatory to studies of the catalytic effects of different acids in non-aqueous media, it was decided to repeat some of the previous work which has been done on this reaction and to extend it to include other solvents and mixtures of solvents.

Materials

Acetone. The best obtainable grade of acetone was purified by the method of Shipsey and Werner⁴. Freshly prepared acetone, boiling at 56.15°C. (760 mm.), was used in all determinations. The density, D_{40}^{25} , was 0.7865.

Ethyl Alcohol. Absolute alcohol was prepared by several refluxings with very active quick-lime and subsequent fractional distillations. Freshly prepared alcohol was used in making all solutions. The boiling point was 78.36°C. (760 mm.) and the density, D_{40}^{25} , was 0.7852.

Benzene. Thiophene-pure benzene was purified by the method of Peterson and Rodebush⁵. The boiling point of the purified solvent was 80.07°C. (760 mm.).

Carbon Disulphide. After filtering through dry paper, the disulphide was refluxed for three hours over calcined lime. It was then distilled, and the distillate was treated with dry, powdered potassium permanganate (5 g. per liter). After distillation, the product was treated with purified mercury and fractionated twice from phosphorus pentoxide. The boiling point of the purified solvent was 46.10°C. (760 mm.), and the density, D_{40}^{25} , was 1.2899. It was stored in the dark until ready for use.

Carbon Tetrachloride. The method of purification was the same as that employed by Mills and MacRae⁶. The boiling point of the product was 76.74°C. (760 mm.) and the density, D_{40}^{25} , was 1.5936 and D_{40}^{0} , was 1.63266.

¹ (a) Dawson and Leslie, *Journ. Chem. Soc.*, 95, 1860 (1909); (b) Dawson, *ibid.*, 99, 1 (1911); (c) Dawson and Powis, *ibid.*, 101, 1503 (1912).

² Watson, *ibid.*, 3065 (1927); (b) Hughes and Watson, *ibid.*, 1945 (1929).

³ Cohen, *Journ. Am. Chem. Soc.*, 52, 2827 (1930).

⁴ Shipsey and Werner, *Journ. Chem. Soc.*, 108, 1255 (1913).

⁵ Peterson and Rodebush, *Journ. Phy. Chem.*, 32, 714 (1928).

⁶ Mills and MacRae, *Journ. Phy. Chem.*, 15, 54 (1911).

Chloroform. The method of Cohen¹ was employed to purify chloroform. The boiling point of the product was 61.15°C. (760 mm.) and the density, $D_{40}^{0^{\circ}}$, was 1.5247.

Ethyl Acetate. The method of purification was that described by Wade and Merriam². The boiling point of the purified solvent was 77.20°C. (760 mm.) and the density, $D_{40}^{25^{\circ}}$, was 0.8945.

Ethylene Dichloride. This solvent was dried over phosphorus pentoxide for 24 hours and fractionated twice. The middle portion, boiling at 82.95°C. (760 mm.) was used.

Dichloroethyl Ether. The product of the Eastman Kodak Company was first dried with anhydrous calcium chloride, followed by metallic sodium. The dry ether was then distilled, and the middle portion was used. The boiling point was 172.5°C. (739 mm.).

Bromine. Three extractions were made with 10% sodium hydroxide solution. The bromine was then distilled in an all-glass apparatus, once alone, and twice from phosphorus pentoxide. It was stored in an all-glass container from which the bromine was forced into a calibrated tube.

Method

The reaction mixture consisted of 100 ml. of the solvent, 10 ml. of acetone, and 1.0817 g. of bromine, unless otherwise specified. The mixture was placed in a 250 ml. closed volumetric flask which was immersed in an ice bath. Samples (2 ml.) were withdrawn at intervals. These were immediately diluted with an aqueous potassium iodide solution and titrated with 0.05 N sodium thiosulphate solution.

Results and Discussions

The rate of the reaction was found to be independent of the concentration of bromine but to depend upon the concentration of acetone. This is in keeping with the results obtained with aqueous solutions and lends support to the contention that the reaction whose rate is increased is one involving acetone alone. This reaction probably involves the keto-enol transformation, which would then be the reaction that is catalysed by hydrogen bromide. The bromination of the enol modification is assumed to be instantaneous.

The natural rate of the reaction was studied by adding 1.0817 g. of bromine to 110 ml. of acetone. Cohen, using 0.840 g. of bromine and the same quantity of acetone, found that the reaction was complete in approximately 18 minutes. We found it to be complete, i. e., all the bromine was consumed, in 12 minutes and to show a much more pronounced latent period (Table I) than Cohen observed.

In aqueous solution (Table II) the bromine was completely consumed in 67 hours. Here the reaction showed an initially rapid rate

¹ Cohen, *loc. cit.*

² Wade and Merriam, *J. Chem. Soc.*, 101:2420 (1912).

TABLE I.—Rate of the Reaction in Organic Solvents
N/20 Sodium Thiosulfate (ml. used to titrate 2 ml. sample)

Time (Min.)	Pure Acetone	Carbon Disulfide	Ethylene Dichlo- ride	Carbon Tetra- chloride	Chloro- form	Dichloro- diethyl ether	Ethyl Acetate	Ethyl Acetate + HCl
0	5.30	5.30	5.35	5.30	5.30	5.30	5.05	5.30
1	4.85	4.80	4.90	4.90	4.80			4.90
2	4.80						4.80	4.60
3						5.30		
4	4.80	4.60	4.90	4.90	4.80			1.65
5								1.25
6	4.80							0.20
7		4.50					4.70	0.00
8	4.50					5.25		
9		4.40		4.90	4.80			
10	3.80						4.70	
11								
12	0.00	4.30			4.75			
13								
14			4.85	4.90				
15		1.50	4.70		4.70			
16		0.00					4.70	
17						4.00		
18				4.85	4.60			
20					4.50		4.60	
22			2.70		4.30			
24						1.15	4.50	
25				2.70				
26			0.00		3.00	0.40		
29				0.00				
30					0.20	0.00		
31					0.00			
33							0.40	
35							0.00	

TABLE II.—Reaction in Water

Time		N/20 $\text{Na}_2\text{S}_2\text{O}_3$ (in ml.)
Hours	Minutes	
0	0	5.30
0	1	4.70
0	5	4.60
0	25	4.31
0	40	4.30
1	3	4.30
1	20	4.30
1	58	4.26
4	40	4.20
7	30	4.20
18	45	3.02
22	40	2.60
26	20	2.18
29	30	1.75
42	20	0.80
49	20	0.50
55	20	0.30
67	00	0.00

during the first hours. Suddenly, it practically ceased for a period of approximately six hours; it then became much faster, the rate at which hydrobromic acid was formed increasing with the time. The reaction became slower again after some 40 hours.

Blanks were run for all the organic solvents used in the experiments. Their purpose was to determine whether or not bromine reacts with the solvent to an appreciable extent at 0°C. After six hours, no decrease in the quantity of sodium thiosulphate solution required in the titration could be detected except for alcohol, where a decrease in titre of 0.6 ml. occurred.

TABLE III.—Reaction in Ethyl Alcohol

A.		B.	
Alcohol dried in usual manner (Wt. of Br ₂ =0.9196 g.)		Intensively dried alcohol (Wt. of Br ₂ =0.8107 g.)	
Time in Minutes	(ml.) N/20 Na ₂ S ₂ O ₃	Time in Minutes	(ml.) N/20 Na ₂ S ₂ O ₃
0	3.8 ml.	0	3.35 ml.
12	3.00	12	2.35
26	2.65	22	2.10
41	2.30	38	1.70
51	2.10	43	1.30
62	2.00	48	.95
71	1.80	56	.30
91	1.35	61	0.00
103	1.20		
114.5	.70		
117	.60		
121	.60		
126	0.00		

TABLE IV.—Reaction in Benzene

A.		B.	
Benzene dried in usual manner (Wt. of Br ₂ =1.2342 g.)		Intensively dried benzene (Wt. of Br ₂ =1.089 g.)	
Time (Minutes)	N/20 Sodium Thiosulfate (ml.)	Time (Minutes)	N/20 Sodium Thiosulfate (ml.)
0	5.10 ml.	0	4.50 ml.
1	4.60	10	2.70
24	4.60	15	2.70
59	4.60	20	2.55
71	4.50	25	2.50
81	2.20	33	0.00
86	0.00		

The results obtained when the course of the reaction was studied in carbon disulfide, ethylene dichloride, carbon tetrachloride, chloroform, ethyl acetate, and dichloroethyl ether are shown in Table I. The ethyl alcohol used as a solvent in the experiments reported in Table IIIA was dried in the manner previously described. The results obtained with this solvent could be reproduced to within 5-6 minutes for the period required for complete consumption of the bromine (about 120 minutes in all). Results for other solvents in which the time for complete reaction was shorter could be reproduced to within one minute. Table IIIB shows the results obtained with ethyl alcohol which had been subjected to prolonged and repeated treatments to remove the water originally present. Tables IVA and IVB show the results obtained by using benzene which had been treated, for widely different periods of time, with phosphoric anhydride.

The results obtained with these solvents differ from those reported by others in the following respects:

(1) Dawson and Leslie report that acetone and iodine react more rapidly in methyl alcohol than in benzene or carbon tetrachloride. This result was unexpected. One should expect the course of the reactions in alcohol to resemble that in water more closely than it does the reaction in carbon disulphide or benzene. According to our results in the reaction between bromine and acetone, ethyl alcohol in the role as solvent shows a greater similarity to water than do carbon tetrachloride and benzene. However, the reaction in alcohol is much faster than in water and becomes still more rapid as the alcohol is more completely dried.

(2) The time required for the utilization of all the bromine in the reaction is much less than the time reported by Cohen. We found, for example, that the reaction was complete in 16 minutes when carbon disulphide was used as solvent, in 29 minutes for carbon tetrachloride, and in 31 minutes for chloroform. Cohen's results for the same solvent, although he used less bromine, are approximately 110, 180, and 130 minutes. We believe that Cohen's results are too high and that they are caused by using acetone or solvents which contained appreciable amounts of water. When we added 0.0258 g. of water to 100 ml. of carbon tetrachloride and the usual quantities of bromine and acetone, we found that the reaction was complete in the same period of time as Cohen reports for anhydrous carbon tetrachloride, 180 minutes. This reaction had a very long latent period (over two hours) and then proceeded rapidly to completion.

The effect of small amounts of water in the solutions is also demonstrated by the results obtained in benzene and alcohol. There can be no doubt concerning the powerfully retarding effect of water upon the reaction. This fact supports the belief that molecular hydrogen bromide and not oxonium ion is the catalyst of the reaction.

(3) Cohen overlooked the latent period in all the reactions which he studied. This has been pointed out by Watson, although the latter does not offer any specific information on the point. It was first observed by Dawson and Leslie, whose results, however, like Cohen's,

indicate that the solvents or the acetone used by them contained water, which always increases the time required for the reaction. Our results show a latent period for the reaction in all organic solvents. In ethyl acetate this period is removed completely by the addition of dry hydrogen chloride.

(4) Except in the instance of benzene as solvent, there is no pronounced initial period of activity for non-aqueous solutions as has been shown to be true for the reaction in water. The initial decrease in the titre corresponds almost exactly in every case to the decrease in the concentration of bromine due to dilution when 10 ml. of acetone is added.

(5) The bromination reaction has a high initial velocity in the intensively dried benzene, which is entirely absent in benzene dried in an ordinary way. This cannot be caused by a catalyst originally present in the benzene since the period of activity at the beginning of the reaction was followed by a period of inactivity. One may venture the suggestion that a considerable quantity of enol acetone is present in intensively dried benzene and that this enolic form is brominated instantaneously.

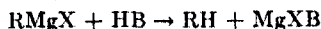
(6) The addition of 2 ml. of pyridine to the reacting mixture in carbon tetrachloride completely stopped the action of bromine upon acetone (for three hours).

(7) The addition of sodium acetate to the reacting mixture in ethyl alcohol retarded the reaction rate. During the first sixty minutes there was scarcely any reaction, whereas in the absence of the salt more than half of the bromine was consumed in the same length of time. Lithium chloride increased the rate of the reaction in ethyl alcohol.

Action of Ammonia on Hexynyl Magnesium Halides

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It is a well known fact that "acidic" substances decompose Grignard reagents as follows,



where HB represents water, alcohols, ammonia, primary and secondary amines, etc.

However, the acetylenic Grignard reagents, $\text{RC}\equiv\text{CMgX}$, are related to the acetylides, and acetylides of first and second group metals are stable to ammonia. It was, therefore, thought of some interest to study the action of ammonia on typical acetylenic Grignard reagents. Hexynyl magnesium chloride and bromide were selected for this work. It was thought that ammonia might favor the following transformation,



rather than ammonolysis. This anticipation was not realized, and ammonia, either liquid or gaseous, was found to decompose the hexynyl magnesium halides, though incompletely. Treatment of ethereal solutions of the hexynyl magnesium halides with ammonia yielded bulky, amorphous, white precipitates. These were filtered, dried, weighed, and analyzed for magnesium, halogen, and ammonia nitrogen. In each instance these data correspond roughly to compositions in accord with the formula,



The reactions affording such precipitates must be complex. A suggested equation, in accord with experimental observations, is:

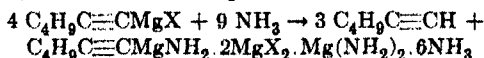


Table I presents the experimental data upon which these conclusions are based.

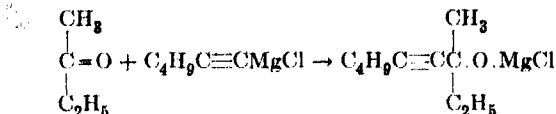
TABLE I.—Experimental Data: Action of Ammonia on Hexynyl Magnesium Halides.

(a) Experiments with $\text{C}_4\text{H}_9\text{C}\equiv\text{CMgCl}$									
Precipitate calculated for $\text{C}_4\text{H}_9\text{C}\equiv\text{CMgNH}_2 \cdot 2\text{MgCl}_2 \cdot \text{Mg}(\text{NH}_2)_2 \cdot 6\text{NH}_3$									
Amount $\text{RC}\equiv\text{CMgCl}$ Mols	NH_3 added as	Analyses of Precipitate							
		Wt. Ppt., g.		Calc. (%)			Found (%)		
		Calc.	Found	Mg	Cl	N	Mg	Cl	N
0.5	gas	58.81	61.9	20.68	30.15	26.80	21.81	30.87	27.70
0.5	liqd.	58.81	62.5	20.68	30.15	26.80	16.95	29.00	26.46

(b) Experiments with $C_4H_9C\equiv CMgBr$
 Precipitate calculated for $C_4H_9C\equiv CMgNH_2 \cdot 2MgBr_2 \cdot Mg(NH_2)_2 \cdot 6NH_3$

Amount RC≡CMgBr Mols	NH ₃ added as	Analyses of Precipitate								
		Wt. Ppt., g.		Calc. (%)			Found (%)			
		Calc.	Found	Mg	Br	N	Mg	Br	N	
0.5	gas	81.04	86.1	15.01	49.31	19.45	14.09	48.90	19.17	
0.5	liqd.	81.04	88.7	15.01	49.31	19.45	14.13	51.09	19.25	

That ammonia causes incomplete ammonolysis is shown also by other facts. For example, addition of methyl ethyl ketone, *after ammonia*, gave a 14.3% yield of 3-methyl-4-nonyne-3-ol:



In a similar manner, butyl bromide gave an 8% yield of 5-decyne and diethyl sulfate gave a 6.4% yield of 3-octyne. These reactions indicate clearly that the ammonia had decomposed the Grignard reagent incompletely.

Experimental

Materials.—Butyl acetylene was obtained by a modified Picon synthesis¹. Dry magnesium turnings and ether distilled from phosphorus pentoxide were used in every case.

Action of Liquid Ammonia on Hexynyl Magnesium Chloride.—To one-half mole (12.16 gm.) of magnesium turnings covered with dry ether in a three-liter three-necked flask, equipped with a mercury stirrer and a reflux condenser, was added ethyl chloride through a dropping funnel. The flask was cooled in a water bath, and the stirring was continued during the addition of the ethyl chloride.

Then one-half mole (41.0 gm.) of butyl acetylene in an equal volume of dry ether was added drop-wise to the ether solution of ethyl magnesium chloride. After all the butyl acetylene had been added, the ether solution was refluxed until all the ethane and unreacted ethyl chloride were driven off. After replacing the condenser with a long piece of glass tubing, used as a vent, the flask was cooled in a bath of carbice and acetone. Then 1.5 liters of liquid ammonia was slowly introduced to the reaction flask through the dropping funnel. The addition of liquid ammonia caused a milky-white precipitate to form which had a tendency to cake on the side of the flask unless vigorous stirring was employed.

Stirring was continued for a half hour; then the entire mixture was filtered through a large funnel. The process of filtration required

¹ Vaughn, Hennion, Vogt, and Nieuwland, 1937. Journ. Org. Chem. 2, 1. Hennion, 1938. Proc. Indiana Acad. Sci., 47, 116.

from three to four hours, and even after that time the precipitate was still very pasty. After the liquid ammonia evaporated from the filtrate, the remaining liquid was distilled, and 18.5 gm. of butyl acetylene was recovered.

The precipitate, a pasty white mass, was dried over concentrated sulfuric acid in a vacuum desiccator. Since the acid absorbed so much ammonia, it was necessary to change the acid at least three times before the precipitate reached a constant weight. The final product was a fine, white, flaky powder which obtained a constant weight after one week's drying. This white powder was analyzed for magnesium, chlorine, and nitrogen.

Action of Gaseous Ammonia on Hexynyl Magnesium Chloride.—One-half mole (70.46 gm.) of hexynyl magnesium chloride was prepared in the same manner as described above. At this point the dropping funnel was replaced by a piece of glass tubing extending just above the surface of the liquid. With continual stirring gaseous ammonia was introduced into the reaction flask until no more precipitate was formed. After adding 200 cc. of dry ether the resulting mixture was filtered and treated as described above.

Action of Liquid Ammonia on Hexynyl Magnesium Bromide.—One-half mole (92.68 gm.) of hexynyl magnesium bromide was prepared and treated with liquid ammonia in the same manner as described for the treatment of hexynyl magnesium chloride with liquid ammonia except, of course, that ethyl bromide was used as the starting reagent in place of ethyl chloride.

Action of Gaseous Ammonia on Hexynyl Magnesium Bromide.—This experiment was carried out in a manner similar to that described under the action of gaseous ammonia on hexynyl magnesium chloride. After analyzing this precipitate for magnesium, bromine, and nitrogen, 80 gm. was placed in a two-liter round bottom flask equipped with a reflux condenser. After adding 500 cc. of anhydrous benzene, the mixture was refluxed for one hour in order to extract any free organic matter that might be present in the precipitate. After the mixture was filtered, distillation of the benzene filtrate revealed no dissolved organic matter.

Preparation of 3-methyl-4-nonyne-3-ol.—One-half mole (70.46 gm.) of hexynyl magnesium chloride was prepared by the method described above. After the addition of 1.5 liters of liquid ammonia, the stirring was continued for a short time so as to insure good suspension of the insoluble precipitate. Then one-half mole (36.06 gm.) of methyl ethyl ketone was added slowly to the reaction mixture through the dropping funnel. Stirring was continued until nearly all the liquid ammonia evaporated; then more dry ether was poured into the flask.

The mixture was hydrolyzed with 500 cc. of 10% hydrochloric acid solution. The ether layer was separated, washed with water several times, and then washed with 200 cc. of 20% sodium carbonate solution, washed again with water, and the ether portion dried over anhydrous

magnesium sulfate. Upon distillation a 14.30% yield of the condensation product, 3-methyl-4-nonyne-3-ol, was obtained.

Preparation of 5-decyne.—A similar procedure was followed for preparing 5-decyne as for the synthesis of 3-methyl-4-nonyne-3-ol, except that one-half mole (68.5 gm.) of butyl bromide was added to the reaction mixture in place of the methyl ethyl ketone. A 7.95% yield of 5-decyne was obtained.

Preparation of 3-octyne.—In preparing 3-octyne the same procedure was followed as given above, except one mole (154.14 gm.) of diethyl sulfate was used, according to the mechanism proposed by Thorn, Hennion, and Nieuwland². A 6.35% yield of 3-octyne was obtained.

Summary

Ammonia has been found to decompose hexynyl magnesium halides incompletely. The products of such reactions are complex amorphous precipitates, insoluble in ether and in liquid ammonia. Hypothetical formulas have been ascribed to these materials: $C_6H_9-C\equiv MgNH_2 \cdot 2MgX$, $Mg(NH_2)_2 \cdot 6NH_3$, where X represents Cl or Br.

² Thorn, Hennion, and Nieuwland, 1936. Journ. Am. Chem. Soc., 58, 796.

Molal Boiling Point Constant for Butylacetylene

G. F. HENNION and JOHN GONCHER,
University of Notre Dame

Butylacetylene (1-hexyne) constitutes an excellent example of an aliphatic hydrocarbon readily prepared in pure form¹. As a part of a research program concerning substituted acetylenes it was decided to determine the molal elevation of the boiling point for butylacetylene. The data have revealed that neither the triple linkage nor the labile hydrogen cause undesirable effects in the cases studied.

Six solutes were selected for the experiments. Each was of Eastman grade. The butylacetylene was prepared as previously described¹. The McCoy apparatus was used with a Beckman thermometer. The essential data are given in Table I. For the sake of simplicity, the volume of each solution was considered to be the volume of the solvent. The density was taken as 0.7108. The constants (K_b) given are, therefore, close approximations only and are expressed as degrees per mole of solute in 1000 grams of solvent. The values were calculated from the expression

$$K_b = \frac{m(\Delta t)G}{1000 g}, \text{ where}$$

K_b = B. p. constant

m = mol. wt. of solute used

G = wt. of solvent used

g = wt. of solute used.

Independent work in this laboratory² on the vapor pressures of acetylenes has shown that butylacetylene has a molal heat of vaporization of about 7586 calories at its normal boiling point, 71°. This value permits calculation of the boiling point constant by means of the equation

$$K_b = \frac{R(T_1)^2}{L_v n_1}, \text{ where}$$

R = gas constant

T_1 = b. p. of solvent in degrees Kelvin

L_v = molar heat of vaporization

n_1 = moles of solvent per kilogram

Substituting,

$$K_b = \frac{1.985(71+273)^2}{7586(1000/82)} = 2.54^\circ$$

¹ Hennion, 1927. Proc. Indiana Acad. Sci., 47: 116-121.

² Rich and Hennion, Unpublished work, this Laboratory.

The calculated value, 2.54° , is only in fair agreement with the experimental average, and no value as high as 2.54° was ever found.

TABLE I.—Molal Boiling Point Constant Data for Butylacetylene

Solute	Grams Solute	Grams Solvent	Δt	K_b
p-Dibromobenzene..... (M.W., 235.9)	0.2500	14.9	0.145	2.04
	0.4000	21.2	0.160	2.01
	0.5000	24.9	0.175	2.05
Diphenyl..... (M.W., 154.1)	0.3019	17.4	0.260	2.31
	0.4038	11.7	0.540	2.42
	0.6438	18.1	0.520	2.26
Naphthalene..... (M.W., 128.1)	0.3002	13.1	0.390	2.19
	0.6002	18.5	0.550	2.17
	0.2008	12.8	0.370	2.22
m-Dinitrobenzene..... (M.W., 168)	0.3000	12.4	0.315	2.19
	0.4000	19.0	0.270	2.26
	0.5000	22.4	0.290	2.18
Benzophenone..... (M.W., 182.1)	0.3000	12.8	0.285	2.26
	0.4000	15.3	0.310	2.16
	0.5000	20.3	0.290	2.14
Stilbene..... (M.W., 180.1)	0.2006	11.4	0.230	2.36
	0.3012	22.0	0.180	2.38
	0.4000	12.4	0.410	2.30
Average value of K_b				2.21

Summary

1. Butylacetylene is an aliphatic hydrocarbon readily prepared in pure form and entirely suitable for many molecular weight determinations by the boiling point method.

2. Experimental values for the molal boiling point constant for butylacetylene indicate a value of about 2.21° per mole of solute in 1000 grams of solvent.

Nitration of Saturated Hydrocarbons

H. B. HASS,
Purdue University

Although nitroparaffins were first produced by Victor Meyer¹ in 1872 by the metathesis of alkyl iodides and silver nitrite it was eight years later that Beilstein and Kurbatov² first nitrated a paraffin. They were investigating the nature of an American petroleum, and, having previously shown that naphthenes (cycloparaffins) could be nitrated, they treated with nitric acid a fraction boiling in the region of heptane. In this way they were able to isolate pure normal heptane, but they also obtained a product boiling at 196-200°C. which was a mixture of mononitroheptanes.

Since the nitration of aromatic hydrocarbons had proved to be a preparative tool of the first importance, it is not surprising that a number of investigators took up the study of the analagous reactions of the alkanes. Francis and Young, Markovnikov, Konovalov, Nametkin, Worstall, Buc and Hopkins, and Poni and Costachescu are some of the workers who took part in these researches. The paraffins nitrated ranged from isopentane to dodecanes; a number of cycloparaffins and also the aliphatic side-chains of aromatic hydrocarbons were found to be capable of the same reaction. A number of patents³ describe the nitration of high-boiling petroleum distillates. The constitution of the hydrocarbons comprising these products is still completely unknown so that it is not easy to ascertain to what extent these workers were dealing with nitration of aromatic, olefinic or saturated hydrocarbons.

Results obtained in the liquid-phase nitration of saturated hydrocarbons at temperatures from 20° to the boiling point of nitric acid showed that the ones most readily attacked were those containing a cyclic tertiary carbon atom; these were followed by those with an acyclic tertiary carbon atom and finally by the naphthenes and paraffins free from tertiary carbon atoms. In general, the nitroparaffins obtained contained the same number of carbon atoms as the hydrocarbon nitrated, although Beilstein and Kurbatov⁴ isolated a dinitroisobutane from the nitration products of a petroleum fraction boiling from 40°-50°C., which was presumably free from isobutane (b.p. -10.2°C.). The reaction showed a marked selectivity for the substitution of tertiary and secondary hydrogen atoms, in many cases producing substantially only one of the isomeric nitroparaffins theoretically derivable from a given alkane. When isobutane was nitrated in this laboratory in vapor phase at a temperature of 150°C., the product was tertiary nitrobutane of 99%

¹ Meyer, 1872. Ber. 5:203-5, 399.

² Beilstein and Kurbatov, 1880. Ber. 13:1818.

³ Ellis. The chemistry of petroleum derivatives. 1:1052-4.

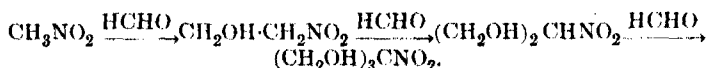
⁴ Beilstein and Kurbatov, 1881. Ber. 14:1620.

purity; the reaction under these conditions behaving as if it were in the liquid phase.

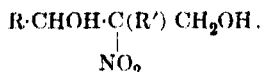
At higher temperatures, however, the vapor-phase reaction gives results quite different from those obtainable under the conditions previously described. Thus *n*-pentane⁶, upon nitration at 400°C., yields all three of the simple substitution products, i.e., 1-nitropentane, 2-nitropentane and 3-nitropentane, but also nitromethane, nitroethane, 1-nitropropane, and 1-nitrobutane. These results are in harmony with those obtained upon every paraffin whose vapor-phase nitration at high temperature has been carefully studied. Every mononitroparaffin is obtained which is theoretically derivable by adding a nitro group to the free radicals obtainable from a given hydrocarbon by fission of a C-H or a C-C bond. Whether or not free radicals are actually involved in the nitration is still not finally decided, but the perfect accuracy of the free-radical mechanism in predicting the identity of the nitro-paraffins obtained lends it an air of probability.

From the viewpoint of the synthetic organic chemist, the ready availability of the primary and secondary nitroparaffins is of interest because of the variety of chemical reactions which these substances will undergo. Thus primary nitroparaffins are hydrolyzed in the presence of strong mineral acids to form first hydroxamic acids and then the carboxylic acids having the same number of carbon atoms as the nitroparaffin used. If desired, the reaction may be stopped at the hydroxamic acid stage. This reaction promises to make hydroxylamine more readily available for large-scale syntheses than has been true in the past.

Both primary and secondary nitroparaffins undergo condensations of the aldol type when allowed to add aldehydes in the presence of a mild base. An illustration of this reaction is the following:



When formaldehyde is used for the reaction, all of the hydrogen atoms attached to the carbon atom holding the nitro group can take part in the condensation. This is also generally true when nitromethane is used regardless of the aldehyde. When nitroparaffins of two or more carbon atoms are condensed with aldehydes of similar complexity, only one molecule of aldehyde reacts per molecule of nitroparaffin. Compounds can be produced, however, of the following type by successive condensations, using formaldehyde and one of its homologs:

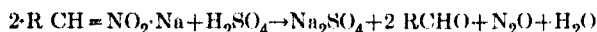


Nitroparaffins, nitroalcohols, nitroglycols, and nitroalkanetriols can all be reduced readily to the corresponding amino compounds. The properties of the hydroxyamines thus obtained are suggestive of those of triethanolamine. They may also be converted to the esters of organic or of inorganic acids. Thus nitration of 2-hydroxymethyl-2-nitro-1,3-propanediol in the usual way with mixed acid yields the trinitrate which is a powerful high explosive.

⁶ Haas and Patterson, 1938. Ind. Eng. Chem. 30:67.

Chlorination of nitroparaffins in the presence of a base yields chloronitroparaffins in which the chlorine replaces one or more of the hydrogen atoms attached to the carbon atom holding the nitro group. For example, the chlorination of nitromethane yields chloropicrin which, while no longer of military importance as a toxic vapor, is of distinct value as an insecticide.

Nef⁶ showed that the sodium salt of a nitroparaffin would, upon acidification with sulfuric acid under the proper conditions, yield an aldehyde or ketone depending upon whether it is derived from a primary or secondary nitro derivative.



The nitration reaction therefore offers an easy means of converting saturated hydrocarbons to the following classes of substances: nitroparaffins, amines, hydroxamic acids, carboxylic acids, hydroxylamine and its derivatives (such as oximes), nitroalcohols, nitroglycols, nitroalkanetriols, aminoalcohols, aminoglycols, aminoalkanetriols, the esters of the preceding six classes derived from either organic or inorganic acids (including certain high explosives), and the substituted amides derived from any of the amino derivatives, chloronitroparaffins, aldehydes, and ketones. The exploration of this wide field of synthesis is a fascinating research topic for a number of the members of the Department of Chemistry at Purdue.

⁶ Nef, 1894. Ann. 280:263-91.

Iodine Number of Oil of Peppermint

LAWRENCE H. BALDINGER, University of Notre Dame

Introduction

In the analysis of essential or volatile oils, little or no importance is attached to the determination of the iodine number, inasmuch as other chemical constants for these oils seem to be of more importance in establishing standards of purity and identity. The decoloration of an iodine in chloroform solution by a sample of oil of peppermint in a chance qualitative test suggested the problem of the determination of the iodine values for several samples of this essential oil as a possible aid in determining the purity and commercial value of the oil.

The usual chemical constants which are determined for oil of peppermint include the ester value, expressed as menthyl acetate, total menthol content, free and combined in the form of menthyl acetate, and the menthone content. The United States Pharmacopoeia¹ sets standards for the first two values, requiring not less than 5% of esters, expressed as menthyl acetate ($C_{10}H_{18}O_2$), and not less than 50% total menthol ($C_{10}H_{18}OH$), free and as esters, but specifies no purity rubric for menthone content. Arbitrary values for this substance have been suggested by the large-scale users of this essential oil since it is believed that some of the characteristic odor and flavor of peppermint oil is due to the menthone ($C_{10}H_{18}O$).

Inasmuch as chemical and physical constants had been determined for a number of samples of peppermint oil, it seemed desirable to calculate the possible relationships between the iodine values and the other constants for these oils. While it must be admitted that these relationships are usually of theoretical interest only, it frequently happens that practical ratios do exist between various constants.

Experimental Procedure

For the determination of the iodine values of the oils, a method suggested by F. W. Rosenmund and W. Ruhnhen² was used, a method similar to but faster than the Hanus procedure. Strictly speaking, because of the substitution of bromine for iodine in the reagent, the value might be considered as a bromine value, except for the fact that the milli-equivalent for iodine instead of bromine is used in the calculations.

The reagent is prepared by mixing 8 g. of pyridine and 10 g. of concentrated sulfuric acid with 20 ml. of glacial acetic acid, and to this solution adding 12 g. of bromine in 20 ml. of glacial acetic acid. After thorough mixing, the solution is diluted to one liter with glacial acetic acid.

¹ The United States Pharmacopoeia, 11th. Dec. Rev., Mack Printing Co., 1936, p. 259.

² Rosenmund and Ruhnhen. Pharm. Weekblad. 61:76 (1924); through Year Book of the American Pharmaceutical Association 13:428 (1924).

To determine the iodine number for a sample, 0.5 ml. of oil, accurately weighed, is treated with 25 ml. of the reagent and allowed to stand for 30 minutes. Two grams of potassium iodide is then added and the mixture is diluted with 50 ml. of water. The mixture is allowed to stand for 10 minutes and the iodine liberated by the excess bromine is titrated with N/10 sodium thiosulfate solution. With each group of samples a blank is run under similar conditions. The iodine value is calculated using the following formula:

$$\text{Iodine Value} = \frac{(B - A)(0.01269)100}{W}$$

where *B* is the number of milliliters of N/10 sodium thiosulfate solution required for the blank, *A* is the number of milliliters of N/10 sodium thiosulfate solution for back titration, 0.01269 is the iodine factor for N/10 iodine solution, *W* is the weight of sample. No marked variation of iodine values with length of exposure of oils to the bromine solution was observed (Table I).

The menthol and ester values were determined using the methods of the United States Pharmacopoeia.³ The menthone values were determined, using hydroxylamine hydrochloride in a method formulated from a number of references⁴. The chemical constants are tabulated in Table II. In Table III ratios between the iodine values and the other chemical constants are listed.

Discussion and Summary

The results of the investigation indicate that the iodine number may be of theoretical interest in the examination of peppermint oil samples. Data for a larger number of samples, however, is necessary before the practicability of this constant can be demonstrated. From the data as listed in Table II it will be observed that those oils with high iodine

TABLE I.—Variation of Iodine Values with Length of Exposure of Oil to Bromine Solution

Weight of Oil	Time in Minutes	Iodine Value
0.4470	10	65.7
0.4410	10	66.0
0.4812	15	65.8
0.4401	15	66.4
0.4812	20	66.6
0.3442	20	67.1
0.4771	25	66.6
0.3412	25	67.3
0.3440	30	67.1
0.3414	30	67.2

³ The United States Pharmacopoeia, 11th. Dec. Rev., Mack Printing Co., 1926, p. 259.

⁴ Schimmel Report, 1928:22, 23; 1929:143; 1932:104; 1933:12, 92.

values have low menthol and high menthone contents, whereas those samples with normal menthol and menthone contents have iodine values which vary between 62 and 72. The ratio of the iodine value to the combined ester and menthone values for the latter samples is practically constant, while the samples with low menthol and high menthone values show a slightly lower ratio than the normal samples. With additional data from a large number of samples of all grades it may be possible to propose a range for the iodine value as an aid in establishing the quality of peppermint oil. The investigation is being continued using other iodinating solutions.

TABLE II.—Chemical Constants for Peppermint Oil Samples

Sample Number	Ester %	Menthol %	Menthone %	Iodine Value
1	6.43	53.60	24.32	62.5
2	5.46	52.50	26.86	67.5
3	5.41	50.94	27.47	68.1
4	6.36	52.76	24.98	66.1
5	5.76	49.35	26.77	67.3
6	7.94	50.53	30.08	75.5
7	4.46	39.37	43.11	82.8
8	5.22	39.50	42.31	82.7
9	4.73	41.05	38.02	79.0
10	6.44	51.94	29.88	74.2
11	4.76	49.49	30.28	72.1

TABLE III.—Ratios of Chemical Constants of Peppermint Oil Samples

Sample Number	Iodine Value	
	Ester + Menthone	Menthol
1	2.03	1.17
2	2.09	1.29
3	2.07	1.34
4	2.11	1.25
5	2.08	1.36
6	1.98	1.49
7	1.74	2.10
8	1.74	2.09
9	1.85	1.92
10	2.04	1.43
11	2.00	1.46

Isotopic Exchange Equilibria

WILLIAM H. HAMILL, Fordham University and University of Notre Dame

The utility of isotopic exchange equilibria in accounting for various other equilibria in light-heavy water mixtures has been shown previously by the author.¹ The present work is an attempt to measure reliably some of these exchange equilibria by means of an improved technique, of which the essential improvement over earlier work² is the substitution of the immersed float for the pycnometer and the ability to carry out all operations in vacuum.

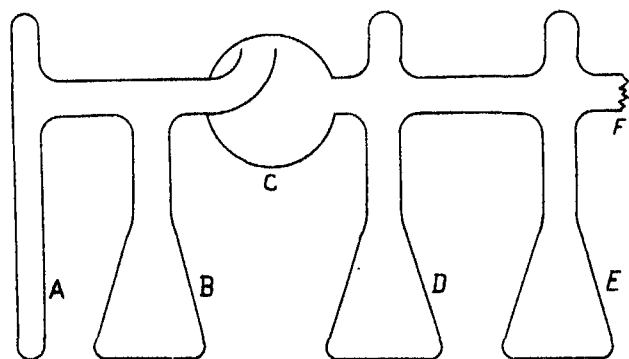


Fig. 1

About one gram of water (16% D_2O or 32% D_2O), which just fills a small ampoule with capillary stem, is weighed in the sealed ampoule and introduced into E (Fig. 1). The substance for exchange is weighed in a small open tube and introduced into D. The float is placed in A, the openings to A, D, and E sealed and D warmed on a water bath while the vessel is evacuated and then sealed at F. The water is liberated by immersing E in dry ice-ether, distilled into B, then poured into A and the density determined; the water is rinsed into C, distilled back to B, etc., and the density redetermined. The water is then distilled into the substance in D, and from D to E to B and the density again determined. This series of distillations is repeated as check.

The temperature is controlled by a glass-walled thermostat constant to $\pm 0.001^\circ$ and temperature differences observed on a Beckmann thermometer calibrated against one with Bureau of Standards certification. A cathetometer is employed for observations of thermometers and floats.

The densities of the floats were determined with reference to potassium chloride solutions whose densities were measured with 25 cc.

¹ Hamill, 1937. Journ. Amer. Chem. Soc. 59:1492.

² Hamill and Freudenberg, 1935. Journ. Amer. Chem. Soc. 57:1427.

pycnometers and were reproducible to ten parts per million. Calibrated weights were employed and buoyancy corrections applied.

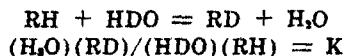
Quartz floats were used, and the temperature of the water adjusted at practically constant pressure (the vapor pressure of water) until flotation equilibrium was reached. Since floats have been employed at constant temperature and varying pressure, it is appropriate to remark that the floats employed here had apparent coefficients of compressibility, referred to water, of about $2(10)^{-3}$ per atmosphere. Since the velocity of the float altered by $0.03 \text{ cm./sec./1}^\circ$, it was readily possible to detect differences in density of one part per million.

Blank runs showed that a negligible amount of atmospheric moisture was adsorbed on the glass walls of the vessel and that spattering, volatility of substance or hydrolytic products and reproducibility of measurements did not affect the density of water by more than one part per million except for hydroquinone which had a slight effect.

TABLE I.

Substance	K (16%)	K (32%)	K (0%)	K (calc.)
$\text{CO}(\text{NH}_2)_2$	0.609	0.614	0.60	0.35
NaOH	0.484	0.578	0.39	
KHSO_4	0.371	0.440	0.30	
KH_2PO_4	0.354	0.372	0.33	
$\text{C}_2\text{H}_4(\text{COOH})_2$	0.572	0.632	0.51	0.55
$p\text{-C}_6\text{H}_4(\text{OH})_2$	0.590	0.632	0.55	

The experimental results are summarized in Table I. A considerable discrepancy is observed between the equilibrium constants at 16% D_2O and at 32% D_2O , this constant being defined by the equations:



where RH is the equivalent of substance with respect to exchanging hydrogen, e.g. $\frac{1}{2} \text{C}_6\text{H}_4(\text{OH})_2$. The observed discrepancies may be due to any or all of the following: (1) fractionation of the water upon distillation and a continuous series of equilibria with the substance in the process of crystallizing from solution, (2) failure of the assumption that in molecules containing two or more hydrogen atoms there is no effect upon other positions due to exchange in any given position, and (3) differences in solubility of RD and RH in the different heavy water mixtures. The first possibility is readily tested, and it was found, by experiments which will not be reported here in detail, that there is no significant trend in K for hydroquinone and succinic acid when up to 90% of these substances is crystallized from solution, by saturating at 100°C . and cooling to 25°C ., before distillation begins. The second possibility may be eliminated by extrapolating K to zero per cent heavy

water, which also eliminates the effects of HDO and D₂O upon solubilities, while the differing solubilities of RD and RH in any given aqueous medium are not susceptible to measurement and must remain as an unknown and possible source of error. The extrapolated constant is given in the table as K (0%) and may be compared, in two instances, with indirectly obtained constants.³ Earlier measurements of K for hydroquinone, by the author, have been employed by Korman and LaMer,⁴ in conjunction with their measurements on the quinhydrone electrode, to calculate several important equilibrium constants. The value of K for hydroquinone reported here is in essential agreement with the earlier measurement.

Summary

Isotopic exchange equilibrium constants have been measured by means of an improved technique for several substances at two concentrations of heavy water. Factors affecting their reliability are pointed out.

³ Hamill, 1937. Journ. Amer. Chem. Soc. 59:1492.

⁴ Korman and LaMer, 1936. Journ. Amer. Chem. Soc. 58:1936.

SECTION ON GEOLOGY AND GEOGRAPHY

Chairman: S. S. VISHNER, Indiana University

About fifty persons were present throughout the greater part of the session of this section. All papers were presented as scheduled. Professor Thomas M. Bushnell, of Purdue University, was elected chairman for 1939.

ABSTRACTS

Some little appreciated features of the desert. E. R. CUMINGS, Indiana University.—Most people who travel through the arid and desert regions of western United States and northern Mexico regard the desert as monotonous or fearsome—a hot, dry, and uninteresting region to be hurried across as quickly as possible. To the geologist who understands the play of weathering and fluvial processes that have shaped desert features, such regions are intensely interesting and even beautiful. The present note, which lays no claim to originality, is intended merely to call the attention of members of the Academy to some of these features—particularly the bolson (intermont basin), pediment, bahada, playa, and fan-bayed and pan-fanned mountains—and to the processes of sheet-flood and stream-flood which have produced these features. Adequate descriptions of these features and processes may now be found in the literature, particularly in the writings of W. M. Davis, W J McGee, D. W. Johnson, and A. C. Lawson, and in the Physiography of the Western United States, by N. M. Fenneman (1931), and the Treatise on Sedimentation (2 ed., 1932) by W. H. Twenhofel and others.

No New Corydon in the Huntington Quarry. E. R. CUMINGS, Indiana University.—The “new” quarry, mentioned by Mr. Breeze (Proc. Indiana Acad. Sci., vol. 47, p. 147) as containing an outcrop of the New Corydon formation, was worked many years ago, filled with water for many years, and pumped out and reopened about 1935, or '36. It exposes the same members of the Liston Creek formation as the France Quarry just west of it, now filled with water, and runs up into a bioherm at its east end. There is no New Corydon formation and no Huntington formation in this quarry.

The taxonomy of Indiana soils and its relation to other natural sciences. T. M. BUSHNELL, Purdue University.—In pedology the soil is defined as a natural body, occurring on the surface of the earth, characterized by conformable layers resulting from modification of parent material by physical, chemical, and biological influences acting through various periods of time. In other words, Soil = material $\times$ forces $\times$ time; but this broad generalization is limited because of the dominance of certain minerals as parent material and by the circumstances which

condition the way the forces act upon the materials. Certain broad world relations result in climatic zones in which certain temperature and moisture conditions are important in soil formation. However, local relief brings about aeration, oxidation, and leaching of convex land forms, while nearby concave land forms may be more or less submerged by water, which results in reduction and in accumulation of organic matter, all of which results in very different soils. The nature and distribution of parent materials are related to many branches of geology. The nature of the forces and the way in which they work on the materials involve physics, chemistry, biology, and climatology. Ecology plays a large part in the way the biological factor affects soils. Since soil taxonomy involves the systematic arrangement of soils according to characteristics which more or less directly result from genetic factors, it follows that certain soil categories become good evidence of past or present existence of various geological, climatic, and ecological facts, and the soil map patterns may show very distinctly the distribution of these facts which belong to other sciences.

The Hazleton Bridge formation of the Upper Pennsylvanian of southwestern Indiana. CLYDE A. MALOTT, Indiana University.—A locally quite fossiliferous formation consisting of 20 to 25 feet of shale, locally containing one or more thin coals, a thin limestone, and a black shale, succeeds the Merom or Inglefield sandstone of the upper Pennsylvanian system in Knox, Gibson, and Vanderburgh counties, Indiana. An excellent exposure of this shale formation occurs near the south end of the White River bridge on U. S. Highway 41 at Hazleton, and the formation may well be named the Hazleton Bridge formation. In this vicinity it occurs between two thick, massive sandstones, the Merom or Inglefield below and the Dicksburg Hills above. The latter receives its name from the circumalluviated hills one mile or more north and northwest of the Hazleton bridge outcrop. Good exposures of the Hazleton Bridge formation occur in the White River bluffs and deep ravines east of Hazleton and in the eastern end of the Dicksburg Hills along U. S. Highway 41 one mile north of Hazleton bridge; in the hills northwest and southeast of Patoka; at many places west and northwest of Evansville, where the formation is 80 to 100 feet above the West Franklin limestone; in the vicinity of Vincennes near old Ft. Knox and along the Robeson Hills bluff of the Wabash River in Illinois; and also at the Embarrass River bluff one-half mile east of Lawrenceville and along the south bluff of Indian Creek two miles south of Lawrenceville, Illinois.

Karst features in the badland shale areas of Petrified Forest National Park, Arizona. CLYDE A. MALOTT, Indiana University.—Numerous small sinkholes occupy many of the slightly rounded and nearly level spur surfaces between the steep-sided ravines in the bare badland Triassic shale areas of the "First Forest," Petrified Forest National Park, east of Holbrook, Arizona. The sinkholes vary from a few inches in depth to as much as 10 feet, making mere dimple depressions to basins 15 or 20 feet across; and in places more or less longitudinal compound basins occur which have many sinkholes. The sinkholes are

variably distributed and do not make any obvious pattern. The shale surfaces are entirely bare of vegetation and consist of a loosened friable veneer over the firm clay shale below. The sinkholes appear to have been formed wholly mechanically and entirely independent of solution. No limestone or other soluble beds are present. Apparently these upland clay shale spur areas dry out in the arid climate, and shrinkage cracks penetrate deeply below the surface. When the infrequent rains occur, much of the water falling on the inter-ravine surfaces enters the shrinkage cracks and reappears at lower levels in the ravines. The partly weathered, friable surface material apparently is carried little by little through the subsurface shrinkage cracks, and the sinkhole hoppers are formed. It may be questioned whether or not these sinkhole forms should be classed as karst. Certainly the region is not a karstland, but karst features frequently occur in regions which are not karstlands. My own view is that these features may well be referred to as karst features, since they are dependent upon the diversion of surface waters to underground routes, a phase present in all karstlands and in the development of many karst features.

Recent oil and gas discoveries in Indiana. M. M. FIDLAR and GORDON F. FRX, Indiana Department of Conservation.—During the past year, four new areas of oil or gas production have been discovered as a result of increased activity in the industry in Indiana. The new oil fields are the Prairie Creek pool in southern Vigo County and the Heusler and Point pools in southern Posey County. None of these three new oil fields have been outlined, and the approximate productive area can not yet be estimated accurately. In the Prairie Creek field, thirteen wells are producing oil at depths of 2,130 to 2,175 feet from three pay horizons in the Devonian limestone immediately underlying the New Albany black shale. Four wells in the Heusler pool produce from the Waltersburg sandstone (Upper Chester) at an average depth of 1,790 feet. The wells in the Point pool obtain oil at an average depth of 2,700 feet in the McClosky oolitic zone of the St. Genevieve limestone, as well as from the Waltersburg sandstone, at a depth of 1,900 feet. The new gas area, the Ogle field, located in central Sullivan County, has four new wells producing gas from a Pennsylvania sandstone at an average depth of 795 feet. The combined initial production of all new wells drilled in the four fields described above total 1,941 barrels of oil and 7,350,000 cubic feet of gas per day. Even though settled production per day will be much lower, these recent discoveries are expected to increase substantially the annual oil and gas production of Indiana. It is also expected that additional important discoveries will be made during the next few months.

Reclamation in the Yakima Valley as a clue to the prospects for the Columbia Basin Project. WALLACE T. BUCKLEY, Indiana University.—The completion of the Grand Coulee Dam will mark another step toward the reclamation of 1,200,000 acres on the Columbia Plateau. The results already achieved in the Yakima Valley indicate that the completion of this project will permit an increase of 312,000 in the population of eastern Washington. Forage and cereal crops now occupy about three-

fourths of the crop land of the several federal projects in the Yakima Valley, but as a source of income the fruit crop ranks first. The already extensive livestock industry is growing. The cereals produced, chiefly wheat, are not sufficient to meet local needs. The expansion of the fruit industry has been limited by a series of unprofitable years, and high freight rates and poor marketing facilities still stand in the way of its development. At present there is an apparent trend toward meeting a general deficiency in dressed meats, corn, and truck crops. At the present rate of population growth, the western states will require the production of about 10,000,000 acres within the next generation. Speculation in land values in the Columbia Basin will probably be rigidly controlled. Settlers will be selected as to experience in farming under irrigation and as to financial stability, and overdevelopment of the land beyond the available water supply will be prevented.

The Far Eastern conflict from the viewpoint of a geographer long resident there. FLOY HURLBUT, Ball State Teachers College.—Six factors of especial significance are: (1) the density of population of both Japan and China; (2) the limited resources for industrialization available in Japan; (3) the advantages of Japan over China due to more stimulating climate, more compact area, greater modernization, greater centralization of government, and greater militarism; (4) the fact that China has resources needed by Japan and affords a large, convenient market for Japanese manufactures; (5) Japan's attempts to break by force the drastic boycotts of Japanese goods in China; and (6) the close timing of Japan's aggression to take advantage of European difficulties. Although Japan is conceded great military superiority, its success to date suggests that its goals are still remote. Appreciation of Chinese qualities and geographic advantages leads not only to a sympathetic attitude but to belief that, in the end, Japan will not accomplish its objectives.

Climatic changes during post-Pleistocene times as indicated by fossil pollen in Indiana bogs and lakes. J. E. POTZGER, Butler University.—The pollen records from Indiana bogs show little fluctuation in climate, progress being remarkably uniform from cool-moist to warm-moist and warm-dry. In the western part of the state a warm and very dry period is indicated by prominence of grass pollen in later deposits. The conditions which controlled spruce-fir forest (cool-moist) changed comparatively rapidly in all parts of the state. Interpretation of climate is made difficult by the fact that pollen of oak and maple cannot well be defined to species and both of these genera have representatives of dry and wet habitats.

Further studies of certain atmospheric variations. A. V. LOTT, Sellersburg.—A circulation in any medium can occur only when a flow in a given direction is completed by a return flow in an opposite direction. This fundamental principle seems to be inseparably connected with all major air-flows throughout the world. When it operates in connection with another principle which causes air masses to become elongated

in the direction of their most rapid motion, it causes great variations in the weather and the climate over widely extended areas. The complete development of an air-flow under the influence of these two principles apparently results in the formation of a complete climatic cycle. In North America the temperate climate becomes sub-arctic and then glacial. The glacial climate may be followed in certain sections by mild moist conditions, which are eventually replaced by another return to arctic cold. The arctic conditions eventually become sub-arctic and then temperate, and the cycle is completed. Charts show just how glacial and interglacial periods may develop in North America.

Geographic background of the Gallup, New Mexico, intertribal ceremonial. FRANK R. HALL, Purdue University.—Several aspects of this annual indigenous ceremonial reflect the geographic environment, for example, the costumes, ornamentation, implements, vehicles, and foods. It affords a view of the native—inherent rather than imported—arts, beliefs, modes, and other factors in Indian life.

Geophysics in the Training of a Geologist

FRED SERVISS, Purdue University

The realization that geophysical methods might be of service in prospecting for ore bodies and likely areas for petroleum accumulation aroused extensive interest on the part of the mining and oil fraternity twenty or more years ago.

The continued increasing demands of modern civilization upon natural resources made it imperative to increase output and to develop new sources of supply. The evident and most likely areas of mineral wealth were either depleted or were being depleted by active mining. This left, as always, the less probable areas for future prospecting and development.

It will be granted that successful prospecting in the beginning was more luck than science. An increasing appreciation of geological control in ore deposition developed, in the old time prospector, a rule of thumb method which was fruitful when applied to exposed ledges. The recognition of the value of gossan, like the variability in the occurrence of gold leading to the prospector's statement that 'gold is where you find it,' is a well-known example. Continued prospecting under these crude beginnings resulted in the discovery of many famous mines. Drake's first oil well drilled in 1859 at Titusville, Pennsylvania, was, as history records, the first application of the anticlinal theory.

The increasing number of producing mines and oil wells served to create, after a time, a desire or what might be termed a need for more raw materials. Since the average rate of depletion of a mine is taken to be fifteen years and an oil field much less, it soon became apparent that to fill this growing demand new areas should anticipate their depletion. From this necessity arose the economic geologist. He brought to the aid of the mining industry an accumulation of knowledge of ore deposition, previous exploration, development, and production. By correlation, both geographical and geological, other areas were indicated as being economically favorable for reconnaissance. Mining engineers and others made possible the extraction of ore at greater depth and by decreasing cost of production made lower grade deposits available to industry.

The rate of discovery has not kept pace with the rate of consumption. Except for petroleum no major source of mineral has been found since 1850, with the exception of the copper in Africa and the lately discovered iron ores of India. No discovery of major value has been found in North America since 1910. The future looks to Asia and Africa for supplies, but it should not be held as patent that all other areas have been completely worked out since we have concerned ourselves to date only with surface or shallow indications. By the law of averages, mineral wealth should lie in the crust in equal or greater

abundance than outcrops imply. Since economic or what may be termed applied geology has been of value in this connection, the profession should make use of any and all branches of science that will aid in this continued search for raw materials.

One of the latest and most promising is the science of geophysics. The science itself is not new; it is only an application of much that has been known for ages.

The use of lodestone, credited to the Chinese, dates back at least 3000 years B. C. The discovery of the laws of magnetic attraction and repulsion, the use of a pivoted needle by mariners, Columbus' discovery of the declination of the compass from the true north, and Gilbert's published *De Magnete* in 1600, which remained without addition until the nineteenth century, is a short history of magnetic phenomena. Modern geophysics has made much use of magnetic methods in prospecting.

Cavendish's experiments, using a crude torsion balance in determining the mean density of the earth, were made in 1798. It was not until the 1880's that Baron Von Eötvös devised a modification using the Cavendish principle and used it in the determination of local variations in gravity caused by rock masses. This principle is used in the modern torsion balance. From its use we have arrived at a conclusion as to the constitution of the earth's interior, and it has played its part in solution of the problem of isostasy.

The first basic statements, dealing with the question of transmission of earthquake waves, were made by Robert Mallet, an Irish engineer, about 1850. He was antedated by Reverend John Mitchell, who in 1760 stated that believed earthquake shocks travelled in a series of waves through the associated rocks. Mallet also suggested that an artificial earthquake could be created by explosions in the ground from which it should be possible to measure velocities of wave transmission. Our modern seismic methods are not so modern after all. Researches along this line have also given more information as to the condition and constitution of the earth's interior, which may be of only academic interest; yet the science and techniques are made use of daily in prospecting for underground information not only for oil but for other purposes.

Electricity and magnetism are closely related in the mind of the physicist; but in geophysics the property of current travel, the development of natural electric currents within the earth (sometimes called the natural battery action), and transmission of radio waves and distortion are separated from pure magnetic properties. Many electrical properties have been determined for rock masses. Delineation of faults, contact zones, the outlining of ore bodies in mineralized areas, and many other applications have given an insight into deeply covered ore zones.

Geologists should be made familiar with the various physical laws noted in the foregoing and their application to modern prospecting. Too few schools at present recognize that such should be part and parcel of geological training. It is not necessary that we train our men as geophysicists since that has become a specialized field, but we should train them in the basic principles on which the science of geophysics is built. The current argument as to whether or not the new science should be taught by the department of geology or the department of physics should

not concern us at the present. That is more pertinent in the training of the specialist as to whether he major in physics and minor in geology or major in geology and minor in physics.

If it be granted that geophysics has a bearing on economic geology, should not our graduates be given some foundation in geophysical principles? This will require, no doubt, a more specialized course in physics specifically designed for this purpose, advanced courses in mathematics beyond the calculus, and a knowledge of mechanics, followed by a general geophysics course. In answer to the question, which is no doubt in the minds of some, as to where we are to find the time in an already crowded curriculum, my answer is—we should evaluate our curriculum—throw out outmoded courses, prune to the bone, and let our graduates be modern in concept and training.

Wind-Polished Pebbles from Northern Newton County, Indiana

M. M. FIDLAR

State Department of Conservation

In the course of field investigations during 1938, the writer had opportunity to visit an interesting area in Lake Township, northern Newton County, near the center of the east line of section 33, T. 31 N., R. 9 W., approximately three miles south of Lake Village along U. S. Highway 41. In this vicinity in comparatively recent years, the stream which drains the northwestern portion of the old Beaver Lake swamp has entrenched itself deeply below the surface of the recent lake-bottom deposits. For thousands of years this area was covered by a vast glacial lake and swamp, but the urge for more farming land led some of the early settlers to dig a small drainage ditch to one end of the water area so as to be able to carry on further agricultural pursuits there. This ditch, owing to the fact that the original swamp area was perched several feet above the drainage lines to the north, was rapidly eroded downward to form the large open ditch in existence at present.

The entrenching of the drainage ditch allowed the wind to gain access to the thick deposit of lacustral white sand which was subjacent to the surface peat or muck of paludal origin. As a consequence of the resulting deflation, the sand was carried away to form small dunes



Fig. 1. White sand pedestal, capped by muck and vegetation, standing near the center of the Newton County blow-out. Pebbles on the floor near this feature are affected greatly by the action of moving sand.



Fig. 2. General view of blow-out. In background is drifting sand along entrenched stream. In foreground are pebbles and pieces of bog iron ore concentrated by the removal of the lacustrine sand by the wind.

to the northeast, following the destruction of the peat cover by under-mining. An interesting pedestal of white sand, capped by muck and vegetation, stands near the center of the area of deflation (Fig. 1). During the existence of the swamp near the line of junction between the peat and the underlying white sand, nodules of bog iron ore were formed by the action of ground water heavily charged with iron minerals. At the site of the blow-out in discussion these nodules of limonite and sand, too heavy to be moved readily by the wind, are concentrated upon portions of the sand floor as the sand is blown away.

The white sand, forming a part of the lacustrine deposits, contains numerous pebbles and cobbles of varying size, which, like the bog iron nodules, are concentrated upon the floor of the blow-out, resembling the "hamada" or pebble pavements of desert regions (Fig. 2). The pebbles of varying composition have been attacked by the particles of moving sand rolled along the surface by the prevailing winds and have attained in some cases a beautiful "windpolish." In many cases partially-buried pebbles have taken on "desert varnish," a phenomenon due to the concentration of iron minerals on surfaces below the ground. Such pebbles, so far as the writer is aware, have never been described from Indiana although they are not uncommon in many arid regions where sand dunes are constantly moving.

The impact of moving sand in the Newton County blow-out does not have the same abrasive effect upon all pebbles. The sandstone fragments show no visible effect of the natural sand-blast although it is possible that such types of stone may be shaped to some degree by the rounding of corners and sharp edges. Shale pebbles seem to react in much the same way as those composed of sandstone. Compact limestone or slaty shale pebbles have assumed a certain amount of wind-polish, and sharp edges have been rounded and smoothed before polish-

ing. Laminated limestone pebbles have been grooved and faceted in a remarkable manner by sand-abrasion in the Newton County blow-out.

Igneous and metamorphic rocks have reacted most impressively to the attack of the driving sand. Granite and related igneous rock pebbles are etched as they lie upon the floor of the blow-out so that the harder mineral grains and crystals stand out in bas-relief. The white sand, composed in the main of quartz grains, readily attacks the mica and hornblende of the granite, whereas the feldspar crystals are only slightly reduced and the quartz grains undergo very little alteration with the exception of the frosting of the surface.

The most pronounced wind-polish has been attained by the pebbles composed of gabbro and basalt, fine-grained igneous rocks. Many pebbles of this composition exhibit rounded edges and wind-shaped facets on the windward side; and all surfaces with which the wind comes in contact are finely polished. On the leeward side, however, the pebbles have the frosted appearance characteristic of glacial pebbles, transported some distance from their parent outcrop, and show no effect of the abrasive action of the wind-driven sand.

Mineralization in the Harrodsburg Limestone

GORDON F. FIX

Department of Conservation

Mineralization in sedimentary rocks, far from any known igneous activity, has been an interesting study in economic geology since such deposits were first discovered. Some of the more important lead and zinc deposits, as well as cadmium and other metals, are present in such environments. Deposits where the minerals are present in quantities great enough to make them of economic importance have been rather thoroughly investigated geologically, but in many areas there are smaller deposits which have not been the subject of much detailed study. The attention of the author was first called to the mineralization in the Harrodsburg limestone by Professor Ralph Esarey, of the Geology Department of Indiana University, and to Professor Esarey he wishes to acknowledge indebtedness for advice and many helpful suggestions, both in the field and in the laboratory. This paper represents a progress report on a study not yet completed. Mineral occurrences, relationships to the limestone, and paragenesis are described for only a limited area. At the present time the study has been extended to include all the Harrodsburg limestone in Indiana, and continued work may modify or completely change theories as herein postulated.

Much of the mineralization in these minor deposits occurs in geodes. These nodular masses of mineral matter occur in many places in the United States, but the most prolific and widespread horizon is in the Lower Warsaw Series of Indiana, Illinois, and Iowa. In this formation the geodes are perhaps the best developed and most abundant and contain the greatest variety of minerals of any place in the country.

In Indiana the Warsaw Series is represented by the Harrodsburg limestone. Perhaps the best exposure of this limestone in the immediate vicinity of Bloomington is in the quarry about one mile north of the city on State Road 37, where from 30 to 40 feet of the formation is exposed in a total formational thickness of from 60 to 90 feet. The floor of the quarry is not more than ten feet above the contact between the Harrodsburg and the Borden or Knobstone. It was from this quarry that most of the specimens were collected for study.

The Harrodsburg limestone is typically coarsely crystalline and contains great numbers of crinoids and bryozoans. In certain localities the formation becomes more shaly. This is especially true in the quarry north of Bloomington where the lower 15 to 20 feet of the 40 feet exposed is a greenish, shaly limestone, interfingering with more calcareous lenses. Toward the top of the section much of the argillaceous material disappears, and the formation assumes the light grey (often bluish), coarsely crystalline, very fossiliferous aspect of the typical limestone. In the zone of oxidation the color changes to a distinct buff or tan due to the presence of the hydrous oxide of iron. The line of

transition between the oxidized or weathered and the fresh limestone is very sharp in most places, there being practically no gradation.

Mineralization in the quarry is not confined to the geodes, some of the best occurrences of minerals being in drusy cavities, along joints, fractures, bedding planes, and stylolites, or disseminated in the limestone close to one of the avenues of lower resistance to mineralizing solutions.

The term "geode" comes from a Greek word meaning earthlike, because the usual form of the geode is spheroidal. Several definitions have been proposed, but none of them quite fills the requirements. Perhaps the best definition is one given by Van Tuyl:¹ "Geodes are rounded or nodular masses formed by the inward growth of mineral matter upon the walls of pre-existing cavities. They may be solid or hollow, depending on whether or not the process of filling has been carried to completion."

The definition, as stated, is too inclusive. Not all masses of mineral matter growing inward from the walls of pre-existing cavities can be classed as geodes. Many are cavities containing only a few crystals or having the walls only partially covered with mineral matter. The term geode should be restricted to those masses having a complete outer siliceous shell and the interior either wholly or partially filled. An amended definition, embodying the restrictions as stated above, follows: Geodes are rounded or nodular masses of mineral matter, having an outer siliceous shell and growing inward by the addition of mineral matter on the interior of the shell. They may contain one mineral or several and may be hollow or solid. Continued deposition tends to produce complete filling.

Typical geodes of the Harrodsburg limestone are practically limited to the lower ten or fifteen feet. They occur mainly in shaly facies; and, although generally small, are well-developed. One stratum about three feet above the floor of the quarry is almost one continuous geode, so closely are they spaced. These are about two inches in diameter and one inch thick, on the average, and are composed of crystalline quartz with subordinate amounts of calcite and rare occurrences of pyrite and sphalerite. This one horizon represents the only definite limitation of geodes to one particular stratum in the vertical section. Elsewhere, geodes are scattered indiscriminately, some areas being almost or totally barren and others having geodes in considerable abundance. The latter fact may be attributed to the greater permeability of one particular area to the percolating solutions.

Intermingled with the geodes and extending up to the top of the section are irregular cavities (druses) ranging in size from one-fourth inch to a foot or more in the longest dimension. Some of these apparently were initial cavities, that is, they were present when the limestone was deposited. An example of this type is the hollow space between the two halves of a brachiopod shell. Others, and by far the most common, appear to be due to differential solution by percolating waters above the water table and along stylolite seams, bedding planes, and joints and fractures. Some cavities, occurring in rather even textured, fresh limestone are difficult to explain either by the initial theory or by differential solution. These are located at some distance from any apparent

¹ Van Tuyl, F. M., 1921-1922. Iowa Geol. Sur. 30: 305.

path for solutions. A possible explanation is that an initial cavity, affording an opportunity for percolating waters to become active, has been enlarged by the solvent action of these waters. An interesting feature of these mineralized cavities is the presence of a number of country rock inclusions within the later mineral matter. Inclusions of this type are not common and occur mainly in those cavities which have a preponderance of dolomite. The presence of inclusions would seem to indicate one of two things: either deposition has taken place on the outside of the initial layer of mineral matter, by replacement of the limestone, at the same time that deposition was taking place on the interior; or, in extremely irregular cavities, small masses of the limestone have been cut off from the rest and included between the crystals, with some replacement.

There are several types of mineralized cavities. One type, which occurs mainly in the geode zone and for a distance of about ten feet above it, is particularly filled with rhombohedral flesh-colored crystals of dolomite with smaller amounts of calcite and tabular crystals of gypsum, with or without quartz. A second type contains calcite with two generations of crystals; a third contains calcite and drusy quartz crystals; and a fourth contains quartz, calcite crystals, and later mammalary calcite and aragonite. The last three types are mainly above the geode zone, and the second is confined principally to the upper 15 feet of the section. Where the zone of weathering comes in contact with the second type, the calcite crystals are coated with limonite. In the limestone immediately adjacent to these cavities, especially those containing dolomite, glauconite, and pyrite, this occurs rather frequently. Sphalerite crystals are common, and millerite has been found in only two instances. Barite was found in one large cavity, with dolomite and calcite.

Along joints, fractures, bedding planes, and stylolites the chief minerals are glauconite, calcite, sphalerite, and pyrite, with little quartz. The minerals are not confined to the surface of the joint or fracture but may partially replace the limestone for a distance of from one to two inches in from the surface. Many fracture planes, which would otherwise go unnoticed, are made conspicuous by glauconite, which not only fills the actual break, but, in many cases, makes a gradational contact with the limestone on both sides. Irregular, vertical veins of calcite occur locally. Considerable limestone has been removed by solution along bedding planes, and a residue, in places one inch or more thick, of very glauconitic argillaceous material has been left. The chief mineral along such planes is pyrite, which is contained in the limestone adjacent to the plane as crystals up to one-fourth inch long. Chalcedony, showing Beekite rings, and calcite occur along stylolite seams. The black material present is mainly carbonaceous matter, with innumerable microscopic pyrite crystals imbedded in it.

It is apparent from a study of the minerals present that there has been a more or less definite order of deposition. This is especially true in the case of the earlier minerals, which are also those occurring most abundantly and consistently. In all cases where the three predominant minerals are present, the order is: quartz, dolomite, calcite. The order

of deposition of the minor minerals is more difficult to determine, since they are present in small amounts and are not all present in one locality. It seems probable that more than one period of deposition has occurred. Crystalline quartz, dolomite, calcite, sphalerite, and some pyrite belong to the first period. Mammalary calcite, aragonite, and more pyrite represent the second period. Glauconite probably belongs to the second period, but its relationships to the other minerals and its low solubility make this a matter of conjecture. Its deposition may have covered a longer period than that of any of the other minerals. Barite, gypsum, and limonite are the latest minerals, the last two having resulted from the alteration of calcite and pyrite. Some examples of the paragenesis of minerals are:

1. Geode: Quartz-dolomite.
2. Druse: Quartz-calcite-limonite.
3. Joint surface: (including one inch of country rock) Calcite-sphalerite-pyrite.
4. Irregular cavity: Quartz-dolomite-calcite- (pyrite inclusion) glauconite-pyrite.
5. Solid geode: Quartz-minute pyrite crystals.
6. Druse: Dolomite-calcite-gypsum.
7. Fracture plane: Glauconite-pyrite.

Several theories have been advanced to explain geodes. One states that a crinoid calyx may be replaced by silica.² Deposition begins between the plates which make up the calyx, and, as more silica is added, the plates are gradually forced apart and finally are engulfed in the silica. Bassler³ says that many of the geodes can be traced directly or indirectly to a crinoidal origin, since there are large numbers of these organisms present in the rocks. He also says that the common brachiopod, *Athyris lamellosa*, may be next in importance. If conditions are right, almost any fossil can be replaced by silica. Some of the geodes of the lower Harrodsburg may have been formed by the replacement of fossils; but, for the most part, the lower beds in the section studied are shaly and not very fossiliferous. In no case was a geode found which had only partially replaced a fossil. Such replacement is common in the geodes of the upper part of the Borden formation.

Van Tuyl⁴ ignores fossils in his theory for the formation of geodes in Iowa and Illinois. He states: "The origin of the geodes in the region studied is believed by the writer to be related to the calcareous concretions which originally must have been very abundant in the beds and which are still preserved in some localities. These nodules, being more soluble than the enclosing rocks, have been in large part removed, thus leaving cavities in which the geodes could be formed. * * * The removal of the calcareous nodules which, it is assumed, preceded the geodes, implies an interval of solvent action during which the beds were above ground-water level. The growth of geodes, on the other hand, undoubtedly took place below the ground-water level."

² Shaler, N. S., 1899. Geol. Soc. Amer. Bull. 10:253.

³ Bassler, R. S., 1908. Proc. U. S. Nat. Mus. 35:133.

⁴ Van Tuyl, F. M., op. cit. 844-846.

The writer does not wholly agree to any theory heretofore proposed, since insufficient evidence has been obtained to date on the Indiana geodes. Continued work may shed some light on this complex problem. In the vicinity of this study there are very few calcareous nodules left; so replacement must have been very complete, if such replacement has taken place. Fossils play an important part in the formation of geodes in the Upper Borden where over-silicification of brachiopods and corals is very apparent. The only fossils occurring abundantly in the lower part of the Harrodsburg in this quarry are crinoid stems; and these, while silicified, do not seem to have contributed in any way to the formation of the geodes. Also, crinoids occur only in the calcareous phases of the Lower Harrodsburg and are not present in the shaly members where the geodes occur.

The source of the minerals seems to be in the limestone itself. The Harrodsburg is overlain by the Salem limestone, which will average close to 96% pure calcium carbonate; and it is underlain by approximately 600 feet of intercalated shales and sandstones, comprising the Borden or Knobstone formation. It is highly improbable that either of these formations could have been the original source of the metallic minerals or that ascending thermal waters could be responsible, because of the widespread occurrence of the minerals. Apparently small amounts of the minor minerals were present in solution, either in the present combinations or in different ones in the Warsaw sea, and were precipitated out along with the lime. Water percolating through the limestone has taken the minerals into solution and redeposited them under favorable conditions. The composition of these solutions must have changed considerably or have been highly complex during the period of deposition, since part of the minerals are soluble in acidic and part in alkaline solutions. The composition also must have varied locally, because the same sequence of minerals is not present in all cases. Change in composition of the solutions probably was the chief factor controlling deposition, although the latest minerals, amorphous calcite and aragonite, and some encrusting chalcedony appear to have been deposited by evaporation.

Nothing can be said definitely as to the time of deposition, because there is nothing on which to base estimates. The process of taking into solution and redepositing obviously covered enormous periods of time and may still be going on in places where the limestone is below the water table. In the quarry studied, however, deposition seems to have been stopped for some time with corrosion of existing crystals and formation of secondary minerals, such as limonite, gypsum, and barite, the latest stage.

The Heavy Minerals of the Mansfield Sandstone of Indiana

H. RICHARD GAULT

University of Missouri¹

Introduction

This investigation was undertaken for the purpose of obtaining any evidence which might distinguish stratigraphic horizons in the Mansfield formation and give information as to its source. With this objective in mind, the writer collected samples and studied sections of the formation throughout the area in which it outcrops during the summer of

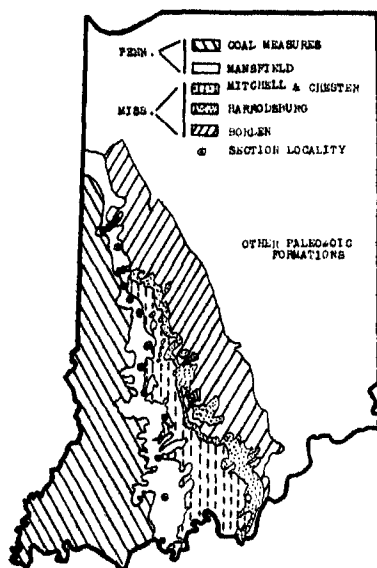


Fig. 1.

1937. A total of 239 samples were taken from 16 localities (Fig. 1), and the material was studied by various laboratory methods, chiefly heavy mineral determinations and mechanical analyses, at the University of Missouri during the school year of 1937-38.

The Mansfield Sandstone

The Mansfield sandstone, named by Hopkins (1) in 1895, is a basal Pennsylvanian sandstone of Pottsville age, resting unconformably on the underlying formations. The stratigraphic hiatus reaches a known max-

¹ Now at The Pennsylvania State College.

imum of about 1500 feet in the northern part of the area, where the Mansfield rests on the New Albany (Dev.) shale near Remington, Indiana (2). Toward the south the Mansfield rests on successively younger formations. In Turkey Run State Park the underlying formation is the Borden (Miss.), and near Greencastle, the Mansfield lies on the St. Louis (Miss.) limestone. At the Ohio River, over 600 feet of Chester (Miss.) sediments lie below the Mansfield (2), in addition to the Borden shale, and the Harrodsburg, Salem, and St. Louis limestones.

The outcrop is a long narrow belt striking NNW-SSE in western Indiana for a distance of some 170 miles along the west flank of the northwest arm of the Cincinnati Arch. The formation is covered by glacial drift in Illinois (3), but the outcrop is continuous across the Ohio River into Kentucky.

The base of the Mansfield is very uneven, having local hills and valleys which sometimes show a relief of 150 feet or more (4). The maximum thickness of the formation in the northern part of the area is less than 100 feet but to the southward increases to over 300 feet near the Ohio River.

The Mansfield is a brown, red, purple, buff, tan, or white sandstone at the outcrop with occasional local conglomeratic, shale, and coal phases. The color depends on the amount and nature of the iron oxide present and changes from section to section, although differences in surface color in individual sections are ordinarily slight.

The sandstone is usually massive, but thin-bedded phases are present. Cross-bedding is a characteristic feature of the Mansfield sandstone. The sandstone is medium-grained, the majority of the grains ranging from .15 mm. to .6 mm. with sub-angular to sub-rounded shape. Modification of the quartz grains by secondary growth is quite evident. The chief cementing materials are silica and iron oxide, although rarely calcium carbonate and pyrite cements were noted. Despite the secondary growth on quartz grains, the friability is determined largely by the amount of iron oxide cement. In most cases the sandstone is easily crushed.

Field and Laboratory Procedure

A sample of the fresh rock was taken every five feet vertically in each section. All samples were crushed and coned and quartered until a portion weighing about 25 grams was obtained. This portion, from which the excess iron oxide was removed with warm dilute hydrochloric acid, was used in the heavy mineral separation. All samples were washed by decantation to remove the fine material.

The heavy liquid employed in the separation was tetrabromoethane (Sp. gr. 2.9), a modification of the procedure described by Milner (5) being used. The heavy liquid was washed from the grains with naphtha and recovered by evaporating the naphtha.

The actual study of the heavy fractions was made with a binocular microscope. Several samples were studied in great detail and the minerals identified by the oil immersion method with a petrographic microscope. Whenever a new mineral or a new form of a previously

known mineral appeared, a petrographic microscope was used for positive identification. Approximately 400 grains of the entire fraction of each sample were counted and the percentages of each mineral computed from this count. The light fractions were cursorily examined under a binocular and petrographic microscope to determine the minerals and the amount and variety of feldspar.

Minerals of the Mansfield Sandstone

Light Minerals.—The light minerals (Sp. gr. less than 2.9) in the Mansfield are quartz, feldspar, and chert.

Quartz.—The quartz grains generally compose 95% or more of the sandstone and range in size from .05 mm. to .6 mm. The larger grains are frequently well rounded and frosted, but the smaller grains are more angular and clear. Secondary growth has taken place to some extent on most of the grains, with the later quartz in optical continuity with the original grain. Almost all quartz grains carry inclusions of rutile, gas bubbles, or unidentified particles.

Feldspar.—Feldspar grains do not exceed 2% in the samples studied. In the order of abundance the varieties are orthoclase, microcline, and probably albite (Ab^m), for a few grains have fine plagioclase twinning striations with indices equal to or below 1.540. Most grains are cloudy and anhedral, but some grains are clear or have clear borders and are subhedral. It is not known whether the clear borders indicate authigenic growth.

Chert.—Usually the percentage of chert is less than two, although some conglomeratic phases consist quite largely of reworked chert from the St. Louis limestone.

Heavy Minerals.—The heavy minerals make up a minor portion of the sand, less than 1% by weight. The following minerals with a specific gravity of more than 2.9 were identified; biotite, brookite, chlorite, garnet, hornblende, ilmenite, leucoxene, magnetite, muscovite, pyrite, rutile, tourmaline and zircon.

Biotite.—The biotite grains are cleavage flakes which have been battered and bent. All grains have been bleached to some extent and occasionally approach muscovite in color.

Brookite.—Brookite was identified by its optical properties: indices of refraction much greater than 2.06, birefringence very high, and positive biaxial interference figure with very strong dispersion. It occurs as tabular and prismatic grains, brown to yellow in color and usually cloudy in transmitted light. The average size of the grains is .05 mm.

Small well-developed crystals are sometimes found projecting from leucoxene grains which resemble the material identified as brookite in form, color, and often in size. These crystals were probably developed *in situ*, as evidenced by their sharp edges and the soft nature of the leucoxene matrix. The action of moving water would soon tear the crystals loose from such soft material.

McCartney (6) describes a similar occurrence in the Chester sands

of Indiana and also concludes that they were developed *in situ*. The small crystals were identified by McCartney as brookite, but Tyler and Marsden (7), in an X-ray study of leucoxene, worked over McCartney's slides and could not identify brookite.

Chlorite.—Thin books and flakes of chlorite with smooth white edges range in color from deep bright green to light silver green. Biotite is usually present in those samples containing chlorite.

Garnet.—A light pink variety of garnet is most common, but dark, almost opaque varieties, and light cinnamon colored grains were seen. The light colored grains often show a rectangular patterning and are not worn. The dark brown grains are sub-angular. Grains vary in size from .1 mm. to .4 mm.

Hornblende.—Dark green cleavage flakes of hornblende are present. All grains observed were fresh in appearance.

Ilmenite.—Ilmenite occurs as sub-angular to rounded grains which have a sub-metallic luster. Very rarely ilmenite was found altering to leucoxene. It is recognized that other opaque minerals may have been confused with ilmenite.

Leucoxene.—Leucoxene grains are smooth and polished, white to buff or even brown, and also earthy, porous, and sometimes pitted. Micro-crystalline material, almost opaque under the petrographic microscope, was identified as leucoxene and may be an early stage in the alteration of this mineral to rutile or brookite. Grains of this description were fused with borax and the purple titanium bead obtained. Brown (8) has also reported leucoxene of this same general description. The description of Tyler and Marsden is typical of the material in the Mansfield.

Magnetite.—The octohedral habit is the most common form, but occasional grains are nearly spherical. The crystal forms and magnetism serve to distinguish magnetite from ilmenite. The grains average .1 mm. in diameter.

Muscovite.—Clear ragged flakes of muscovite are most abundant. Aggregates of very fine material occur, and, in samples rich in mica, small books of clear muscovite with smooth white edges are numerous. The white edges seem to be the result of bumping and grinding between coarser material.

Pyrite.—Pyrite occurs in the form of aggregates and clusters with some poorly developed cubes of pyritohedrons. The crystal forms and the cementing nature indicate that the pyrite is secondary.

Rutile.—Rutile grains are straw yellow to fox-red and silver gray to black. The dark grains have a strong, satiny, metallic luster showing a deep, rich, ruby red color in transmitted light. The light colored grains are rounded whereas the dark grains are sub-angular. Lath-shaped and knee-shaped grains were found occasionally.

Tourmaline.—The dominant color of the tourmaline is brown with green, blue, grey, and colorless grains much less common. The shades of brown vary from almost colorless to nearly black. Light green and blue grains are more abundant than the dark shades. The black and

deep brown grains are at times spherical, pitted, and frosted. The common shapes are long prismatic grains with fractured ends, biscuit-shaped fragments, and irregular grains. Grain sizes range from .06 mm. to .4 mm. averaging .15 mm. Some tourmaline grains contain unidentified inclusions.

Zircon.—A pink variety is the most abundant, but purple, pale yellow, and colorless grains also appear. A complete gradation from purple to colorless is found. Spherical grains and prismatic forms with rounded terminations prevail, but prismatic grains with slightly worn or fresh pyramidal faces occur in every sample. The yellow and purple varieties are spherical and frequently frosted. Grains vary in size from .04 mm. to .2 mm. but the average is .1 mm. The larger sub-hedral grains often carry inclusions of crystals and other material.

Mechanical Analysis of the Mansfield Sandstone

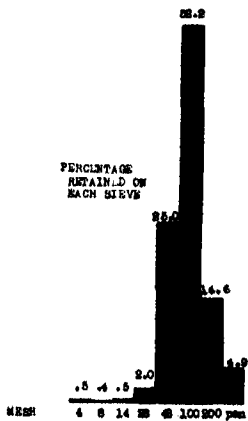


Fig. 2.

In addition to the heavy mineral studies, the writer also made mechanical analyses of 222 samples to determine the size distribution of the sands. The accompanying histogram (Fig. 2) is made from the average figures of all samples. All tests were made on a Tyler Ro-Tap testing machine. The effective size is .100, and the uniformity coefficient is 2.66. The majority of the individual analyses show good sorting, and their cumulative curves are similar to those of the St. Peter made by Dake (9).

Discussion of the Heavy Mineral Suite

The dominant allothogenic minerals of the 239 samples studied are leucoxene and zircon, with ilmenite, tourmaline, rutile, muscovite, and brookite, common but less abundant. Biotite, chlorite, garnet, hornblende, magnetite, and pyrite occur sporadically.

Heavy Mineral Percentages

Persistent Minerals	Sporadic Minerals
Leucoxene 40-70%	Chlorite
Zircon 20-50%	Biotite
Ilmenite 5-20%	Garnet
Tourmaline 5-20%	Hornblende
Rutile 1-10%	Magnetite
Muscovite 1-10%	Pyrite
Brookite 1-10%	

A change in the percentage of leucoxene results in a change in the percentage of zircon, but there is no change in the percentage of the other minerals. Ilmenite is more or less abundant than tourmaline in a particular section, but the relative percentages for each locality do not

vary greatly. Rutile grains constitute about 5% of the heavy fraction in the majority of samples, and the lighter colored varieties are more numerous. Muscovite is usually low except in shale samples. Brookite may disappear almost completely from any one sample or series of samples but is present in all sections.

The sporadic minerals may be present in all samples, but the amount is so slight that they could easily be missed in the grain counts. Chlorite and biotite are usually associated with each other. Garnet grains were seen in very small numbers and in many samples were not observed. The pyrite is probably secondary in all cases.

The heavy mineral species of the Mansfield are uniform in their occurrence and distribution. The suite is always the same regardless of regional location or stratigraphic position. The percentages of individual minerals vary somewhat from sample to sample, but the relative magnitude for each mineral is constant.

The suite is not characterized in any way by mineral content, peculiarities, or percentages which would permit the differentiation of the Mansfield into units within itself or distinguish it definitely from some other sandstones. Evidence for this statement is presented below in the discussion of the source of the sediments. It would be unwise to use the heavy minerals for placing the Mansfield in well logs. Perhaps with information about the formations above and below the Mansfield, such as heavy minerals, insoluble residues, lithologic characters, and paleontological evidence, the data presented in this paper might be of some value for that purpose. The heavy mineral suite alone, however, is inadequate evidence for recognizing the presence of the Mansfield in wells or for correlation between wells and outcrops.

Source of the Mansfield Sediments

The dominant heavy minerals are few in number, are all very stable minerals, and may well have had a long previous history as clastic grains. It appears, then, that the immediate source should be sought for in pre-existing sediments.

Schuchert (10) states that at the beginning of the Pennsylvanian, the United States was a lowland surrounded on the south and east by a mountainous borderland. Cumings (11) pictures the Mansfield sea as having its eastern edge near the eastern edge of Indiana. During the interval between the deposition of the Mississippian and Pennsylvanian sediments, Mississippian and older rocks were extensively weathered and the less stable minerals removed. The area covered by the Mansfield sea was underlain by sedimentary rocks, and the land mass to the northeast and east had many sediments exposed. On the advance of the Mansfield sea, the source, then, of most of the detrital material was the old erosion surface, and the greater part of the material had undergone at least two erosion periods. It seems likely that, since the land mass to the northeast and east was adjacent to the Mansfield sea, a greater amount of material would come from this area than from more distant land masses.

The presence of any of the less resistant minerals, for example, the fresh grains of hornblende, may be due to exposure to erosion for

the first time in the Pennsylvanian period of igneous and metamorphic rocks. Russell (12) has shown that minerals, even the less resistant species, may be transported at least 900 miles and show neither wear nor alteration.

It would be difficult to say exactly what pre-existing sediments furnished the Mansfield material. The presence of chert in the sand indicates that the surrounding Mississippian and older limestones were contributors. The distance materials were brought is also a difficult question, but undoubtedly much of it was local, i. e., the area in which the Mansfield now occurs. At Attica, the Mansfield rests on the Borden, and the lower two feet of the Mansfield contains small fragments of the Borden shale. As drainage developed, the later sediments were brought in from more distant places.

The small and constant number of minerals might indicate a very local and protected area of source, but the size of the region studied, the thickness of the formation, and the findings of other writers seem to refute this and support the view that the source area was rather general.

Other writers have reported suites similar to the Mansfield from various formations. Derry (13) reported a similar suite in some Ordovician rocks of Ontario; Thiel (14) and Tyler (15) found a similar group of minerals in the St. Peter sandstone of Wisconsin and Minnesota; McCartney (6) had an almost identical suite from the Chester sands of Indiana; Lucas (16) reported a comparable assemblage in some Pennsylvanian rocks of Oklahoma; Kelly and Beutner (17) found a very small group of minerals, all of which are present in the Mansfield, in some Pennsylvanian sandstones of Michigan which may be time-equivalents of the Mansfield; Cordry (18) found a similar group in Pennsylvanian and older rocks in the Ozark region of Missouri; Brown (8) reported a large amount of leucoxene and other Mansfield minerals in some Permian sands of the Mid-Continent region; and there have been other suites reported in this country and abroad, which, although not quite like the Mansfield suite, yet have a small number and constant number of the more stable minerals most of which are found in the Mansfield.³

These findings show that the heavy minerals of the Mansfield or a similar group are common and evidence that reworked sediments of a general area of some size were the source of the Mansfield detritals. These findings also show that it would be unwise to use the heavy mineral suite alone for identifying the Mansfield as discussed earlier.

McCartney suggested that the Chester sands represented material from igneous rocks with no intermediate period of deposition. The writer questions the lack of intermediate deposition but favors, instead, the idea of a similar origin of the Chester sands as for the Mansfield.

Acknowledgments

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³ See abstracts in Boswell (19).

laboratory and in the preparation of the paper; to Professor E. R. Smith, of DePauw University, for aid in the field and the reading and presenting of this paper; and to Dr. C. A. Malott, of Indiana University, for information and aid in locating sections.

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Indiana Data on Lightning, Hail, Squall-Wind, and Tornado Frequencies and Damage

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Lightning

Data on the frequency of lightning storms in Indiana are gathered incidentally by the regular, full-time weather bureau stations, which report on the frequency of nearby thunderstorms. Thunderstorms occur on about 50 days each year in central Indiana, on about 45 days in northeastern part of the state, and on about 55 in the southwestern corner. During the summer each locality has an average of about two thunderstorms each week. Lightning from distant storms, too far away to have local significance, may be visible on one or two additional nights a week in summer. Most thunderstorms cover only about one-third of the state and many of them cover less area than that. Moreover, sometimes two or even three thunderstorms affect a locality during a single 24-hour period. Hence, it is probable that about 200 individual thunderstorms occur in Indiana each year.

As it takes the average thunderstorm about four or five hours to cross the state and there are an average of hundreds of lightning flashes per hour, it is quite possible that millions of bolts of lightning are discharged in Indiana each year. Of these a few thousand strike trees, buildings, fences, or the ground. Most of the taller trees, especially the more isolated ones, have been struck at one time or another. Telephone, telegraph, and power lines are frequently damaged. Lightning is a major cause of fire to farm buildings. The U. S. Weather Bureau investigated the average annual fire losses to farm buildings caused by lightning as recorded in an eight-year period, 1915-1922. A recent official map shows that in Indiana nearly a half-million dollar loss a year is caused thus. The average annual totals for certain states are as follows: Indiana \$491,000, Ohio \$685,000, Illinois \$1,094,000, Michigan \$289,000, Kentucky \$266,000, Pennsylvania \$656,000, Missouri \$478,000, Iowa \$611,000, Minnesota \$305,000, Oklahoma \$784,000, and New York \$838,000.

In Indiana lightning causes most fires in summer, chiefly because lightning is much more frequent then. The higher air temperatures of summer and the fact that the combustibles are often dryer than in the cooler months also is more conducive to the rapid spread of summer fires.

Thousands of livestock are killed annually by lightning in Indiana. From the reports of those cooperative observers who have taken especial pains to gather data on these losses in Indiana (for example, Fred Baker of Rockville, Parke County), it seems probable

that on the average more than 4000 hogs are killed annually in Indiana and more than 1000 cattle.

Several hundred people annually are killed by lightning in the United States, seven a year in Indiana, on the average (according to mortality data in the Statistical Bulletin of the Metropolitan Life Insurance Company, June, 1936).

The mortality in four southeastern states (Georgia, Florida, Alabama, and Mississippi) and in three Rocky Mountain states (Colorado, New Mexico, and Arizona) is nearly four times as great as in Indiana in proportion to population. In several other states, however, the death rate is considerably less than in Indiana. This is particularly true for the states with many people living in cities, where very few people are killed in proportion to population, and in the states on the Pacific Coast and New England. In the Pacific States there are few thunderstorms in the lowlands as there is little summer rainfall. In New England thunderstorms are relatively uncommon, and likewise, the population is largely urban.

By the conventional census divisions, the death rates per million population are: Rocky Mountain states 8.3, East South-Central states 7.1, South Atlantic states 6.0, West South-Central 5.6, West North-Central states 3.4, East North-Central states, which includes Indiana 2.1, Middle Atlantic states and New England 1.3, Pacific states 0.2. In deaths per ten thousand square miles, however, the rates are different, and Indiana is in the second class, less unfortunate than Kentucky, Ohio, and West Virginia but worse off than most of the nation.

Although the chances of being killed by lightning are very small in Indiana, almost negligible in the cities, some readers may be interested to learn of ways of reducing the chances.¹

Hail

Violent thunderstorms are frequently accompanied by hail; occasionally hail falls in sufficient quantities to cause considerable damage.

Indiana had, during a 15-year period recently studied by the U. S. Weather Bureau (1916-1930), an average of 4.8 damaging hailstorms each warmer season (April 1 to September 30). Indiana had fewer hailstorms recorded officially as "damaging" than any nearby state, except Illinois and Missouri, which had about as many in proportion

¹ In this connection the following are also helpful:

U. S. Dept. Agr., Farm. Bull. 1512, 1926.

U. S. Bur. Stand., Handbk. 17, 1936.

The following extract may be justified here:

"(a) Do not go out of doors or remain out during thunderstorms unless necessary. Stay inside of a building where it is dry, preferably away from fireplaces, stoves, and metal objects.

"(b) If there is any choice of shelter, choose in the following order: 1. Large metal or metal-frame buildings. 2. Dwellings or other buildings protected against lightning. 3. Large unprotected buildings. 4. Small unprotected buildings.

"(c) If remaining out of doors is unavoidable, keep away from: 1. Small sheds and shelters if in exposed location. 2. Isolated trees. 3. Wire fences. 4. Hilltops and wide open spaces.

"(d) Seek shelter in a cave, a depression in the ground, a deep valley, the foot of a steep cliff, in dense woods or a grove.

to area. In contrast with Indiana's 4.8 damaging hailstorms a year are the following annual average totals: Ohio 8.3, Illinois 6.9, Kentucky 6.2, Michigan 12.6, Wisconsin 8.9, Missouri 5.2, Iowa 21.6, Montana 21.6, and Kansas 33.4.

Data on the extent of damage from hail in Indiana are not yet available. This is partly because hail seldom causes extensive damage in this state. In certain states where more damage is done, more data have been accumulated. For example, in Iowa, which has more than four times as many damaging hailstorms as Indiana (twice as many in proportion to area), the property loss averages more than ten million dollars a year. In a single county, representative of the northwestern part of the state (which has more hail damage than the state average), hail caused an average property loss of \$227,000 a year for a 15-year period. If Indiana's hail damage is proportionate to that of certain comparable areas in other nearby states, the property damage is in excess of \$1,000,000 per year on the average.

Occasionally hailstones reach the size of baseballs or even larger. Large hailstones occasionally kill even people in some parts of the world. Indeed, some scores of hail-induced-fatalities occur annually, on the average, in southeastern Europe and southwestern Asia. None in Indiana, however, are known to the present writer.

Rarely the hail is so small as to closely resemble snow. A remarkable summer snow storm in Indiana is worthy of mention here.

"The most remarkable warm season snowfall in Indiana occurred on July 2, 1924, in Wabash county. There, with the temperature at the nearest Weather Bureau Station nearly 70 degrees, during a hail storm, snow fell to a depth of eight inches on a small area."

An account of this remarkable fall was published in the Bulletin of the American Meteorological Society for August, 1924, and the report was investigated by J. H. Armington, state director of the United States Weather Bureau, Indianapolis, who was convinced of the correctness of the report. This remarkable snowfall was associated with a violent hailstorm which had a distinct tornado-like funnel. Hail covered the ground for some distance around the patch of snow.

Squall-Winds

Violent windstorms, nearly all of the thunderstorm-squall type, cause extensive loss in Indiana. Indeed, for the 20 years of a recent special study by the U. S. Weather Bureau (1916-1935) Indiana suffered a total estimated property loss of \$7,656,000 from violent winds not tornadoes. This was one-fiftieth the total loss for the nation as a whole for such storms. As there are 48 states, it might seem that Indiana has had only slightly less than its proportionate share of such loss, but Indiana is a small state. In proportion to area, Indiana (with 7.66 million loss) had more property damage from violent windstorms not tornadoes than did Ohio (5.15), Michigan (9.3), Missouri (3.3), Minnesota (5.9), Kentucky (6.3), Iowa (7.3), Illinois (9.7), or Wisconsin (10.7).

Thunder-squall damage occurs occasionally in all parts of the state. Among the seasons it is decidedly most frequent in summer. Indiana's

losses in five-year periods were as follows: 1916-1920, \$1,005,000; 1921-1925, \$2,408,000; 1926-1930, \$3,912,000; 1931-1935, \$330,000. The average annual loss is about \$383,000, but the variation from year to year is great. Indiana's greater than average recorded loss for squall winds may be due partly to the fact that the State Director of the Weather Bureau, J. H. Armington, has made especial efforts to gather information of this type. Much of Indiana has, however, more than the average number of farm buildings per square mile, more telephone and similar poles than most states, and because of the earlier settlement than true for most of these states, more old buildings.

Tornadoes

A study of tornado frequency in the United States made by the U. S. Weather Bureau disclosed that for the 20 years, 1916-1935 inclusive, Indiana had 66 tornadoes or an average of 3.3 per year. This number was larger than for Michigan (3.0 a year) or Kentucky (1.2), but smaller than for Illinois (4.0), Wisconsin (4.3), Missouri (6.6), or Tennessee (3.6). Indiana has only about one-fourth as many tornadoes as Iowa or Kansas (15 or 14.6 per year respectively). These latter states are much larger than Indiana, however. In proportion to area, Indiana has about one-half to one-third as many tornadoes as the states wherein they are most frequent, Iowa to Arkansas, inclusive.

In the approximately 2,800 tornadoes recorded in the United States during the twenty years, 1916-1935, 5,224 people were killed by tornadoes; and property losses in excess of \$230,000,000 were sustained. Losses in excess of \$100,000 were sustained in 375 tornadoes although million dollar losses were caused by each of 30 tornadoes.

Partly because tornadoes have played only a minor role in Indiana, no detailed account of Indiana's tornadoes has yet been prepared. With few exceptions, tornadoes damage only a minute fraction of the area of the state. So few occur and the damaged strip is so narrow that the chances of any one spot being hit by a tornado are very small. It has been calculated, for example, that even in the part of our country where tornadoes are most frequent (southern Iowa, Missouri, Arkansas, and eastern Kansas) the chances that any given half-mile square of land (160 acres) will be crossed by a tornado in a century is only 1 to 1600. As most tornadoes devastate a strip only a few hundred feet wide, a farm might be crossed several times without the buildings being demolished. Many buildings are damaged without the inhabitants being killed.

In Indiana tornadoes are least rare in the lower Wabash Valley of the southwestern part of the state. They are next least rare in central Indiana. They are very rare at the surface near Lake Michigan and in the more rugged parts of the state. Bloomington, for example, has not been appreciably damaged by a tornado during its history, which extends about 120 years. Presumably this is largely because a wide belt just west of the city is quite rugged. Tornadoes which cross rugged areas tend to rise above the surface where they do little or no harm.

Indianapolis, in the midst of a plain, has been affected by several

tornadoes, three in one decade. But fortunately no very severe one has plowed through the city. A moderately severe one, that of May 18, 1927, demolished many buildings in the western part of the city, then rose above the surface passing over the downtown part of the city. It caused a property damage estimated at more than \$2,000,000 but only two deaths.

The question of whether or not it may be possible to cause tornadoes to rise above the surface and thus be rendered almost harmless is of interest.

Tornadoes are violent whirls, started by opposing winds and associated with sharp contrasts in temperatures. They occur only when sharp vertical temperature gradients are present. They are formed in the clouds and extend down to the ground only where the temperature of the surface air is relatively warm (as compared with the higher air). Tornadoes rise above the surface again wherever the surface air is relatively cool. Evidence on these points is extensive. For example, tornadoes are most numerous, as to time of day, when the surface air is relatively warm in the early evening. Occasionally, to be sure, a tornado which started in the afternoon continues on its course until midnight but only if the surface air is relatively hot. Records show that the few nocturnal tornadoes occurred on nights when because of cloudiness and high relative humidity nocturnal cooling had been slight. Tornadoes after nightfall occur on "hot sultry nights," never the reverse.

In their seasonal distribution, also, tornadoes are most numerous at seasons when the vertical temperature gradient is greatest. For the mid-west this is during the spring. In the south the temperature gradient is greatest and tornadoes most numerous, earlier than here, in the early spring. Conversely, in the northern states and southern Canadian provinces temperature gradients are greatest in the summer, and hence tornadoes are most frequent then. In certain other parts of the country along the southern Atlantic coast, for example, temperature gradients are often great in the autumn; and hence tornadoes are relatively frequent then.

The influence of temperature gradients on tornadoes is illustrated in other ways. For example, although several tornadoes have entered the western outskirts of Chicago, none have closely approached Lake Michigan. When tornadoes occurred, winds from off Lake Michigan cooled the downtown part of the city. Finally, at Tokyo, Japan, on September 1, 1923, several typical tornadoes developed as a result of the conflict of air movements produced by the great fire and the cooler higher layers of air associated with the typhoon. Excellent photographs of two of these tornadoes indicated that they were closely comparable with those of the mid-west.

If the presence of a surface layer of relatively cold air causes an approaching tornado to rise above the cool air, as appears almost proved by the foregoing data, then a city on a plain, such as Indianapolis, if it could be bathed in cold air on the approach of a tornado, would be thereby protected because the tornado would rise above the buildings and people.

Tanks of rustless steel containing air compressed to say 20 atmos-

pheres (300 lbs. per square inch) could be buried at various points throughout the city, being especially numerous in the western end of the city and just west of the down-town district. Such tanks should be connected electrically with the office of the U. S. Weather Bureau in the city. When telephone reports and supplementary evidence indicated that a tornado was almost at hand approaching the city, the official should close the electrical switch which permits the covers of the tanks to fly off, allowing the compressed air to escape rapidly.

The escaping air would greatly lower the temperature of the surface air, producing a protective cold layer over which the tornado would rise. The cost of maintaining the tanks, including the interest on their installation, would be great; but at present some millions of dollars are expended annually in Indianapolis for tornado insurance premiums. And although insurance reduces the individual's loss, it does not reduce the total loss.

Indiana Distribution and Yield of Corn, Wheat, and Oats*

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Indiana has been an important agricultural state because much of it has climatic, soil, and topographic conditions favorable for the growth of valuable crops, because there is a market close at hand, and because many competent, informed farmers live within its borders.

In this article the distribution and yield of three chief crops, corn, wheat, and oats, are discussed, the basis being the annual county totals and averages reported by the U. S. Census and the U. S. Department of Agriculture Coöperative Crop Reporting Service at the Experiment Station, Purdue University. The special purposes of this study are to disclose the relative importance of these crops in the various parts of the state, with recent changes therein and the relative yields received in the average, favorable, and poor years. These factual data are presented chiefly by maps. Some attempts are made in the text to interpret or explain the contrasts most conspicuous on the maps. The present paper is an elaboration of certain topics discussed in more general terms in earlier ones.¹

Corn Distribution

Corn is grown on almost every representative Indiana farm. On the average for the state, about 25 acres per farm is devoted to corn. The average farm of the southeastern and also of the northern counties has about 15 acres and of the hilly south-central counties about 10 to 12 acres; in the large region called central Indiana, on the other hand, the average farm has about 30 acres of corn even though it includes a total of only 80 acres.

A map of the counties showing the number of acres devoted to corn for the average of ten recent years, not published here because of lack of space, discloses that most counties of central Indiana have between 60,000 and 90,000 acres of corn, depending partly on the size of the county. The largest county totals are found in the northwestern part of central Indiana where two relatively large counties, Benton and Tippecanoe, devote, on the average, somewhat more than 100,000 acres to corn. Several other counties also approach that total. In the Wabash lowland of southwestern Indiana, the county acreage in corn is almost as great as in much of central Indiana, several counties having more than 50,000 acres. In most of the rest of southern Indiana, however, the county totals are less than 30,000 acres; in six counties they are less than 20,000 acres.

* Read in the General Session of the Academy.

¹ Visher, S. S., 1927. Geography of Indiana agriculture. *Proc. Indiana Acad. Sci.* 37:101-116; *Econ. Geog. Indiana* pp. 108-149. New York, 1923.

Since the counties vary in size, it is illuminating to compare the average acreages devoted to corn with the total area of the county. Figure 1 shows the percentage of the total land area which has been planted to corn during a recent decade. This map discloses that on the average more than one-quarter of all the land (which includes roads, railroads, towns, and cities) is devoted to corn in much of central Indiana, where each average square mile has about 180 acres of corn. Three large areas devote more than 30% of all their land to corn. The largest of these is Benton and two adjacent counties; other high counties are Clinton and Tipton, north of Indianapolis, and Hancock, Rush, and Shelby, east and southeast of Indianapolis.

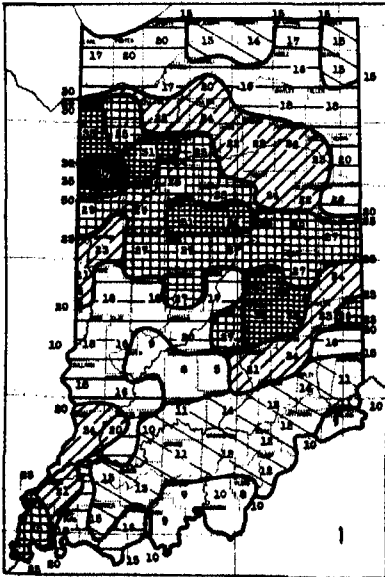


Fig. 1. Corn: Percentage of total land area which is planted to corn (15 year average, 1923-1937).

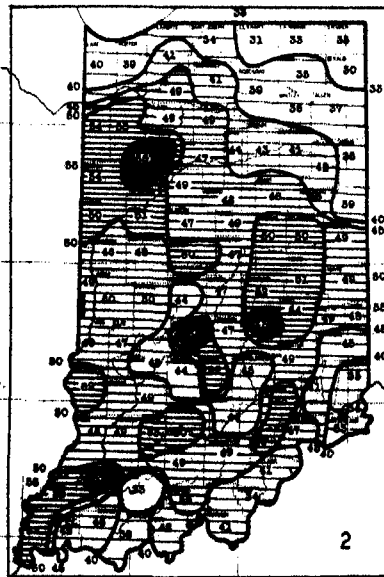


Fig. 2. Corn: Percentage of cropland planted to corn (10 year average).

A large part of southern Indiana, except the Wabash lowland, devotes less than 15% of its land area to corn, which is also true of 4 northern counties. In other words, they have less than 90 acres per average square mile. Eight southern counties devote less than one-tenth of their total area to corn; Brown County only one-twentieth.

The percentages of the cropland devoted to corn are dealt with in Figure 2, which affords a number of surprises. Even where, as in Brown County, only one-twentieth of the total land area is in corn, more than half of all the cropland may be so used. This means that considerable areas are planted to corn in successive years. This map makes conspicuous, in a way not so easily shown otherwise, that corn is a major crop in almost all parts of the state. Only in Dubois and 4 extreme northeastern counties is less than one-third of the cropland used in any

particular year for corn, and of these low counties the county with least, DeKalb, devotes 30% to corn. In only a dozen additional counties, bordering those just mentioned, plus 3 at the extreme southeast, does corn occupy less than 40% of the cropland. In most of the counties it occupies approximately one-half of the cropland; in seven counties corn occupies 54 to 57% of the cropland. The largest region where corn occupies less than 40% of the cropland, in the northeast one-eighth of the state, is often too cool at night in spring and autumn for good corn growth, because of the relatively high latitude and altitude. The other areas with less than 40% of their cropland in corn contain much hilly land where sheet erosion and gullying has been especially extensive and where the better farmers no longer plant corn on hillsides.

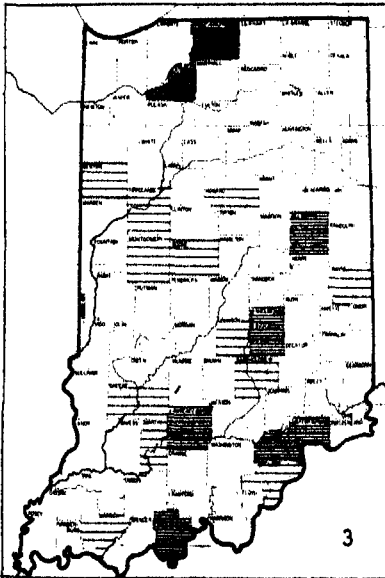


Fig. 3. Corn: Changes in acreages of 10% or more for average of last five years as compared with preceding decade. Inclined shading means gain; horizontal shading, loss; close, 13-15%; light, 10-11%.

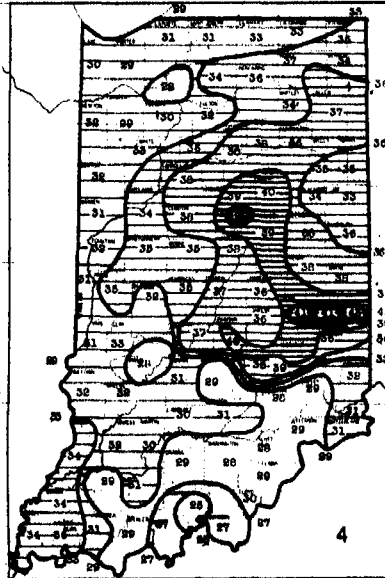


Fig. 4. Corn: Average yields, county averages (15 year averages). Bushels per acre.

Figure 3 discloses the changes in acreages devoted to corn, based on the average of the last five years as compared with the average of the ten preceding years. It shows that in only two counties, St. Joseph and Starke, has there been a gain as great as 10%; on the other hand, there has been a loss of 10 or 11% in many central and southern counties, and a loss of 13 to 15% in six counties, all in the southeastern third of the state. This decline has been encouraged by the soil conservation program of the federal government, but much of it merely continues a decline which has taken place for decades, following serious soil erosion on hillsides and resulting in reduced yields and the cessation of farming

of many tracts.³ Moreover, most of the counties with considerable declines (Fig. 3) still devote more than half of their cropland to corn. This means that "corn follows corn." In other words, crop rotation is incompletely practiced, despite the ever louder expert urging that rotation pays. As more and more farmers come to practice complete rotation, the areas devoted to corn will decrease until nowhere will more than half of the cropland be devoted to corn.

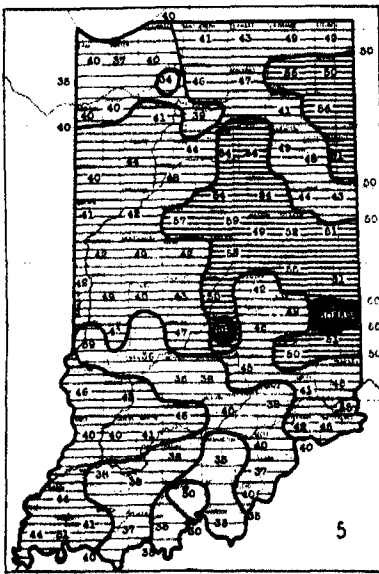


Fig. 5. Corn: Maximum county average yields (highest in 15 years, 1920-1936, except 1921-1922). Bushels per acre.

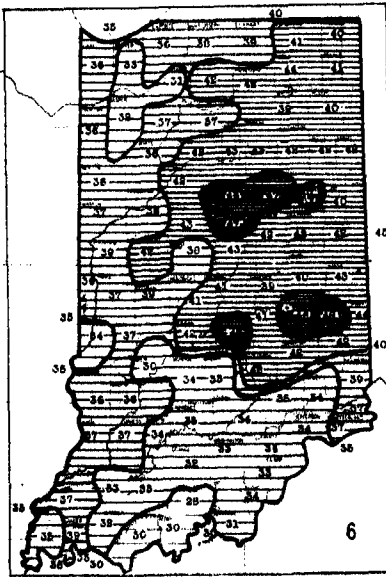


Fig. 6. Corn: Yields in a good year (county average). Only in the best two years of a decade are higher yields received. Bushels per acre.

Average Corn Yields

Despite the fact that Indiana has an exceptionally dependable climate and consequently far less fluctuation in crop yields than have most regions, nevertheless, there is considerable variation from year to year. Hence an average based on a considerable number of years is notably more accurate than the yield for a short period. Figure 4 shows the yields by counties from an average of 15 recent years. It discloses that two large areas have an average yield of 29 bushels per acre or less; an area which is even larger receives an average of over 38 bushels. By far the larger of the poorer areas is in southern Indiana and includes thirteen counties, three of which (Harrison, Perry, and Crawford) receive an average of 27 bushels per acre or less; indeed, the 15-year average for Crawford County is only 25 bushels per acre.

³ Visser, S. S., 1937. Indiana regional contrasts in soil erosion and their chief causes. *Proc. Indiana Acad. Sci.* 46:143-159.

The highest average yields of corn are received in east-central Indiana, extending from Grant and Tipton counties to Rush, Johnson, and Union. In this area yields of 39 or more bushels are normal. In other words, farmers here have a right to expect nearly half again more corn per acre than the average farmer of the one-fourth of the state where corn yields are relatively low. The counties with highest corn yields for the average of these 15 years are Grant and Johnson, where the average is 40 bushels, Rush and Fayette with 41, Tipton 42, and Union 43.

The wide variation among the counties in average yields is related to variation in soil, temperature, rainfall, and in the percentage of the rain which soaks into the ground. Of course care and seed also count. The northwestern area with lower than average yields has much sandy or mucky soil, and it also has relatively frequent drouths. The southern low-yield area has much thin soil on the sloping land, and the bottom lands are being injured by the transfer thereto of infertile materials eroded from the hillsides. Moreover, some of the level upland has poor "white clay" soil. Likewise, more of the rain in southern Indiana falls as sharp showers, which fact means that more of it runs away and hence less of it soaks in. Only rain which soaks in is really helpful to crops. Abundant data on Indiana's contrasts in rainfall intensity reveal that southern Indiana receives a much larger percentage of its rainfall in hard downpours, much of which runs away if there is any appreciable slope, carrying with it soil.³ The lower yields in southern than in central Indiana are also partly the result of more damage from insufficient rainfall in July and often excessively high temperatures.⁴ Dr. Rose has found that when there are many days with temperatures above 90° the yield suffers.⁵

Maximum Corn Yields

Not only are average yields interesting, but one wishes to know how large a yield may sometimes occur. Of course on choice land in exceptional years, yields of 150 bushels per acre are occasionally received. But what about the average of all the cornfields of a whole country?

Figure 5 shows the greatest county average yield received during 13 recent years for which county records are available. In the year of best corn yields (for most of the state this was 1925 or 1937) 22 counties, one-fourth of the state, had average yields of 50 bushels or more per acre, five counties had averages of 55 to 59 bushels (Allen, Noble, Clinton, Tipton, and Henry), and three counties received 60 bushels or more (Fayette 60, Johnson 61, and Union 62). On the other hand, even in their best year, in one-fourth of the state's counties, the average was 40 bushels or less; in five counties it was 35 or less, and in Crawford it was only 30.

³ Visser, S. S., 1938. Rainfall intensity contrasts in Indiana, causes and consequences. *Geog. Rev.* 28:627-637. (Abstracted in *Proc. Indiana Acad. Sci.* 47:147-148, 1938.)

⁴ Visser, S. S., 1936. Indiana regional contrasts in temperature and precipitation, with special attention to the length of the growing season and to non-average temperatures and rainfalls. *Proc. Indiana Acad. Sci.* 45:183-204.

⁵ Rose, John K., 1932. Climate and corn yield in Indiana 1887-1930. *Proc. Indiana Acad. Sci.* 41:817-821; corn yield and climate in the corn belt. *Geog. Rev.* 26:88-102, 1936.

Minimum Corn Yields

A map, not published, shows the smallest county average yields and may advantageously be briefly described. Although Indiana is deservedly famous for the general dependability of its corn crop yields as compared to Illinois, Iowa, Missouri, and other more western parts of the Corn Belt, nevertheless, in the worst of recent years surprisingly low county average yields have occurred in certain parts of the state. For some sections the worst year was 1930; for others it was 1934 or 1936. For the state as a whole the smallest average yields were received in 1901 (19.8 bushels), in 1887 (20.0 bushels), in 1890 and 1893 (24.7 bushels), in 1934 (24.8 bushels), and in 1924 (25.6 bushels).

Along the Ohio River in south-central Indiana are five counties which received in their worst year recently less than a 10-bushel average, with Harrison and Floyd having averages of only 7.3 bushels. Ten additional nearby counties had 15 bushels or less. Northwestern counties having relatively low yields were Lake and Porter with 11 each, Jasper and Pulaski with 12, and Benton, Warren, and Starke with 14.

The highest average minimum yields in this period are 25 to 33 bushels per acre and are located in east-central Indiana. Tipton, one of the flattest counties in the state favored with good soil, has the highest minimum yield, 33 bushels per acre, more than four times the average minimum yields for two southern counties (Harrison and Floyd).

Normal Range in Corn Yields

In addition to the map of average yield (Fig. 4), of maximum yield (Fig. 5), and of minimum yield (not published here), two maps of the yield in four years out of five have been prepared. One of these shows the yields which are exceeded in four years out of five; in other words, it shows the yield of the next to the poorest year in a decade. The other map shows the yields which are received in the best one-fifth of the years—eight years of each decade do not have yields as high as these. These maps show distinctly better than does Figure 4, of the average yield, which may reasonably be expected. Only rarely are the yields greater than those given in Figure 6 or less than those given in Figure 7.

Figure 6 discloses that in all but the poorest year of a decade, yields of 40 bushels or more have been received as county averages in more than one-third of the state (mostly in the east-central and northeast) and more than 47 bushels in four central and eastern counties. On the other hand, in nearly one-third of the state, mostly in the south, yields in excess of 35 bushels occur only once a decade. In the poorest counties, Crawford to Spencer, yields of over 30 bushels are as unusual as this.

Figure 7 discloses that in the poorest two years of a decade the yields averaged higher than 30 bushels in about one-third of the state and more than 41 bushels in three counties. On the other hand, in much of the state, especially at the south, west, and north, yields of less than

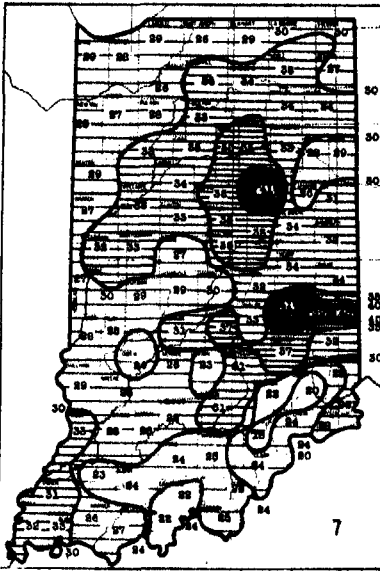


Fig. 7. Corn: Yields in even a poor year. Only the poorest two years of a decade have smaller county average yields. Bushels per acre.

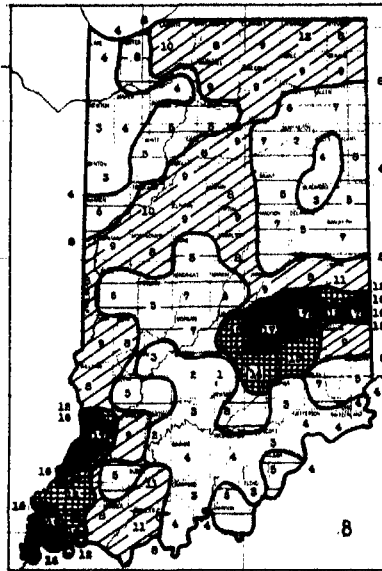


Fig. 8. Wheat: Percentage of total land area which is sown to wheat, by counties (15 year average, 1923-1937).

30 were received in the two poorest years of a decade. In many southern counties yields of less than 25 bushels are as frequent as this, and in five counties yields of less than 22 bushels.

Wheat Distribution

The amount of land devoted to wheat in Indiana is much less than for corn, and there are much wider variations from year to year. This reflects the fact that Indiana's climate is generally not so well suited to wheat, that the yield varies more widely, and that the price fluctuations are more significant. Whereas most of the corn is fed to livestock on Indiana's farms, most wheat is sold in competition with the wheat of other areas, including foreign countries. The fact that Indiana's wheat is soft and not so suitable for bread flour as the harder western wheat is a major reason that much of Indiana's wheat is shipped out of the state to less discriminating bread eaters.

A map of the number of acres sown to wheat for the average of the past decade, not published here, shows that more than 40,000 acres is devoted to wheat on the average in only four counties, all in the southern half of the state. In about one-third of the state 20,000 or more acres per county are sown to wheat. The largest region of this type is in the northwestern part of the state, followed by the southwestern corner and by six counties (Shelby and neighboring counties). Four groups of counties which devote less than 10,000 acres each to wheat are seven situated in south-central Indiana, six at the extreme

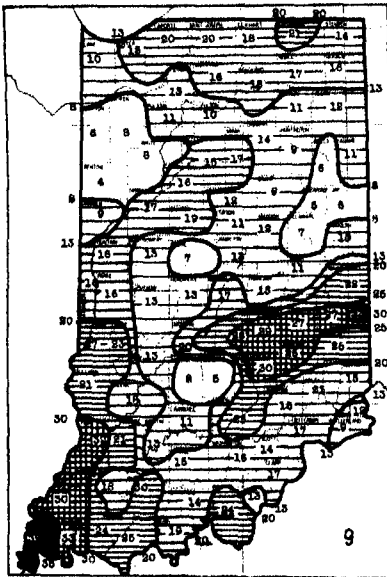


Fig. 9. Wheat: Percentage of the cropland in wheat (10 year average).

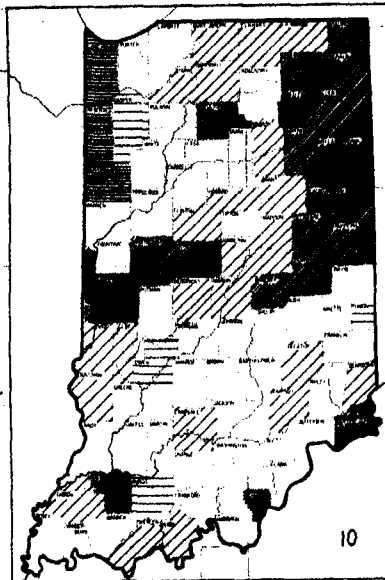


Fig. 10. Wheat: Changes in acreages of 10% or more for the average of last five years as compared with preceding decade. Horizontal lines mean loss; light 10-19%; close, 20% or more. Tilted lines mean gains; light, 10-29%; dark, 30% or more.

southeast, and seven in the north, partly in the northwest and partly in the northeast. Aside from three small counties (Ohio, Blackford and Floyd), the only county having less than 3,500 acres in wheat is Brown, which has only 1,000. The counties with largest average acreages are Knox, 55,800; Posey, 47,400; Shelby, 45,000; and Rush, 43,800.

Figure 8 shows the percentage of the total area of each county which was sown to wheat for the average of the 15 years, 1923-1937. It makes conspicuous the fact that two areas devote relatively large shares of their area to wheat, one at the southwest and the other at the southeast, some distance north of the corner. In these areas about one-sixth of all the land is used for wheat, in Posey County 19%. On the other hand, a large area in south-central Indiana and smaller ones in northwestern and northeastern Indiana devote less than 8% or even less than 4% of all their land to wheat. The southern large area with little wheat contains much hilly land, ill-adapted to wheat; the northwestern area contains much sandy land also unfavorable to wheat. The counties which devote one-sixth or more of their land to wheat are situated in the southern half of the state, rather than in the northern half, partly because the higher average winter temperatures are more favorable.

Figure 9 discloses that in much of the region south of the National Road (No. 40) more than one-fifth of the cropland is devoted to wheat; north of that line an average of only about one-eighth is so used. Ex-

ceptions to the rule that about one-fifth of the cropland of southern Indiana is devoted to wheat are found in Brown (5%), Monroe (8%) and some adjacent or Ohio River counties where about one-eighth or less is so used. Likewise, along the northern border of the state, more of the cropland is devoted to wheat than is true for the average of northern Indiana.

The counties with the largest proportion of their cropland in wheat for the average of a recent decade are Posey 39%, Vanderburgh 33%, Knox 32%, Bartholomew 30%, Shelby 29%. Conversely, the counties with least wheat relatively are Benton, Blackford, Brown, Jay, Delaware and Boone, with from 4.4 to 7%.

Figure 10 shows the changes in the amount of land devoted to wheat for the average of the last five years as compared to the average of the preceding ten years. Whereas 19 counties had shown a 10% or greater decrease in land in corn and only two had shown a 10% or greater increase, the opposite condition prevailed as to wheat. Only seven counties showed more than a 10% decrease; one-third of the counties of the state showed an increase of more than 10%. The decreases are in the northwest and south, and the increases are most general in the northeast quarter; but more than a dozen counties of the southern third of the state also show increases. The increases are largest in the section where relatively little land is devoted to wheat without any obvious reason (see discussion of Fig. 8). Another factor is that in recent years a new variety of wheat has been developed which grows better than those previously available in the northeastern part of the state.

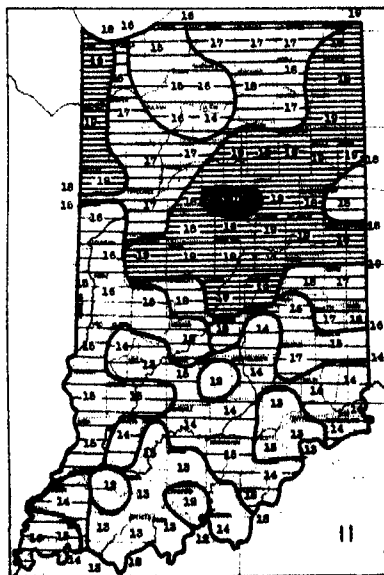


Fig. 11. Wheat: County average yields (18 year average, 1920-1937). Bushels per acre.

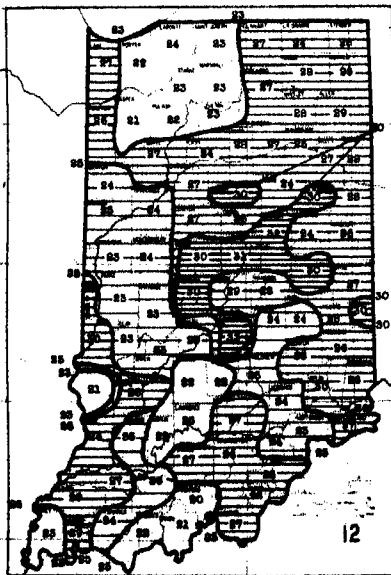


Fig. 12. Wheat: Maximum yields, county averages; highest in 16 years (1920-1937 except 1921, 1922). Bushels per acre.

Average Wheat Yields

Figure 11 presents the county average yields of wheat for the average of 18 years, 1920-1937. The length of this period is significant because wheat yields vary widely in Indiana. This map shows that in a large northeastern and a small northwestern area yields average from 18 to 19.5 bushels, whereas in most southern counties the average is less than 14 and in three is less than 12. The large northeastern area with especially high yields is the one in which the acreage devoted to wheat has increased. In the counties where an exceptionally large proportion of the land is devoted to wheat, the yields are not large, however. This suggests that in those sections considerable land ill-adapted to wheat is sown to it or all of it is not as well cared for as is most of the wheat in the north.

Maximum and Minimum Wheat Yields

Figure 12 shows the greatest county average wheat yield per acre harvested from 1920-1937 (except 1921, 1922, for which strictly comparable data are not available). It discloses that in the best year average yields of 30-33 bushels were obtained in seven central counties but that even in their best year eight northern and nine southern counties received less than 22 bushels, Crawford with 20 being the lowest. The eastern counties fared better than the western ones. For the state as a whole, the average yield was 25.9 bushels in 1931, 21 in 1918, 20.7 in 1906, and 20.0 in 1926.

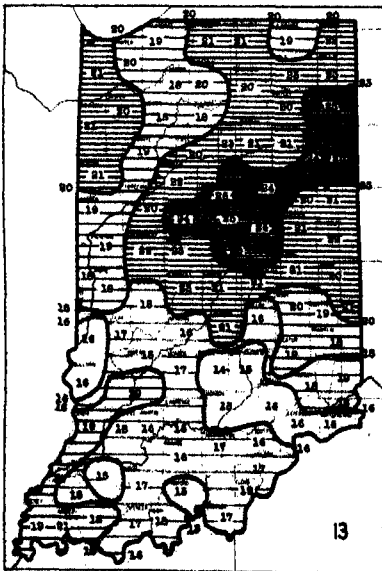


Fig. 13. Wheat: Yields in good years. In the best two years in a decade, even better county average yields are received. Bushels per acre.

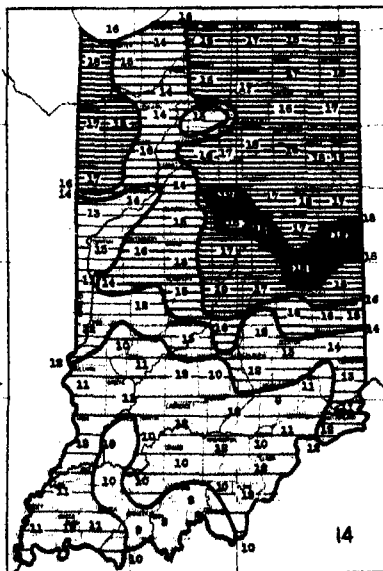


Fig. 14. Wheat: Yields in even a poor year. Only the poorest two years of a decade have lower county average yields. Bushels per acre.

A map, not published, of the smallest county average yields during the 16 years considered in Figure 12 discloses that in poor years central Indiana, except some western counties, had yields of about one-half greater than those received in many southwestern or northern counties and twice as great as Pike, Gibson, Posey, Parke, DeKalb, Cass, La-Grange, and Kosciusko counties, which had averages of only six bushels per acre. Several other southwestern counties had averages of only seven bushels, namely, Harrison, Crawford, Orange, Spencer, Clay, and Vigo, as did also five northern counties, Lake, Pulaski, Fulton, Marshall, and Noble. For the state as a whole, the average wheat yield was only 5.3 bushels in 1900, 8.0 in 1912, and 9.0 in 1896.

Normal Range In Yields

The maximum and minimum yields of record suggest the limits, but from a practical point of view it is even more desirable to know the normal range in yield. Figure 13 shows the yield that can reasonably be expected in a good year. Only the best year in a decade has appreciably larger county averages. This map discloses that in good years wheat yields of 20 bushels per acre are received in the northeastern quarter of the state, the central part of which area receives averages of 23 bushels per acre. On the other hand, all of southern Indiana received less than 20 bushels, much of it less than 18 and ten counties less than 16 bushels.

Figure 14 discloses the yields which may be expected in even poor years but not the very poorest of a decade. In only the three worst years of 15 (1923-1937) was the yield smaller than is shown in this map. It discloses that 16-bushel yields can quite confidently be expected even in poor years in the northeastern quarter of the state and in four northwestern counties but that only one southern county receives yields greater than 12 bushels in such a year, although six receive averages of less than 10 bushels.

Distribution of Oats

Three-fourths of Indiana's counties have devoted for the average of the past decade 10,000 acres or more to oats. The exceptions are in a wide belt parallel with the Ohio River, extending from Gibson to Union county with a short northward extension in central-southern Indiana. Many northern counties devote 30,000 or more acres to oats, and four northwestern counties (Benton, White, Jasper, and Newton) devote from 50,000 to 78,000 acres. The counties with smallest acreages, (aside from the small Fayette, Union, Ohio, Floyd, and Scott counties) are Brown 2,500, Martin 4,000, Clark 4,500, and Jennings 4,500.

Figure 15 discloses that in the southern half of the state less than one-tenth of the land is sown to oats on the average; in the northern half only the northeastern counties have less than one-tenth of their land thus used, and most counties have one-eighth or more of their land in oats. Two large areas, one at the east and the other at the west, have 15% or more of their land in oats; four western counties have more than 20% in oats and Benton County, 30%. At the other extreme, eleven

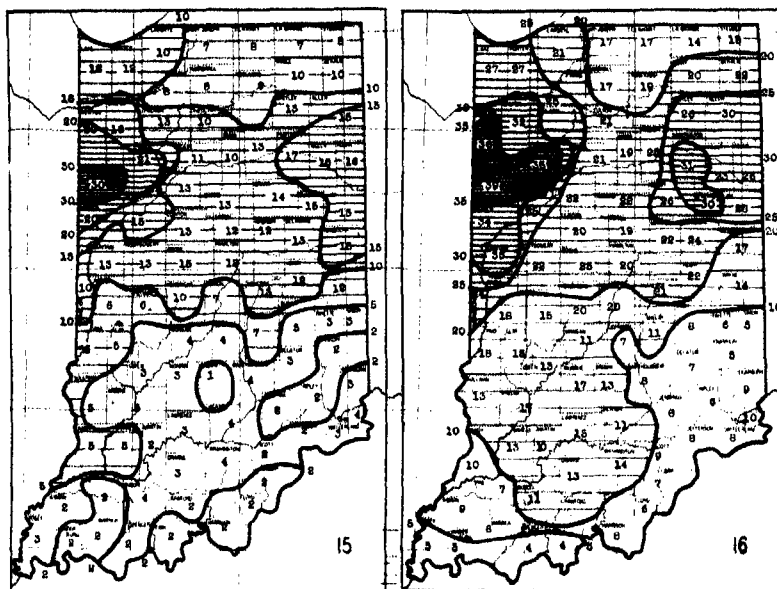


Fig. 15. Oats: Percentage of total land area which is sown to oats (10 year average).

Fig. 16. Oats: Percentage of cropland sown to oats (10 year average).

southern counties have less than 2% of their land area in oats. Brown County with 1.2% has least.

Figure 16, of the percentage of the cropland which is sown to oats, discloses that oats occupy less than one-tenth of such land in the south-east, less than 5% in the extreme south, but more than a quarter of such land in large areas in the northwest and northeast. Benton County leads with 39% of its cropland in oats for the average of a recent decade.

Yield of Oats

The yield of oats varies widely in Indiana. For the entire state it has varied since 1887 from 13.5 bushels per acre in 1934, 17 in 1933, 17.5 in 1890, to 42 in 1917 and 1918, 41 in 1920, and 40 in 1912. The average yield for the state as a whole for 1887-1934 is 29.8 bushels per acre. Figure 17 shows the average yields by counties for the 15 years, 1920-1934. It discloses that in the northeastern quarter yields of 29 or more bushels were average; in most of southern Indiana yields were less than 23 and in seven counties 21 or less.

Figure 18 shows the maximum yield of oats during twelve recent years. During this period no one of the exceptionally favorable seasons for oats is included, and hence the maxima shown are not the highest yields ever received. Nevertheless, the period included two years with a high state average (37 bushels), and hence the maxima shown on this map presumably approach the all-time high. Figure 18 discloses that in

the best year county average yields of 45 bushels per acre or more were received in seven counties in the eastern half of the state with yields of 40 to 45 received in about 25 other counties, all in the northeast two-thirds of the state. In most of southern Indiana the largest county averages were less than 35 bushels per acre and in four counties, chiefly in the southeast, less than 30 bushels.

In the poorest year for oats, yields of 15 bushels per acre or less were received in most counties.*



Fig. 17. Oats: Average yields, county averages for a recent 15 year period. Bushels per acre.

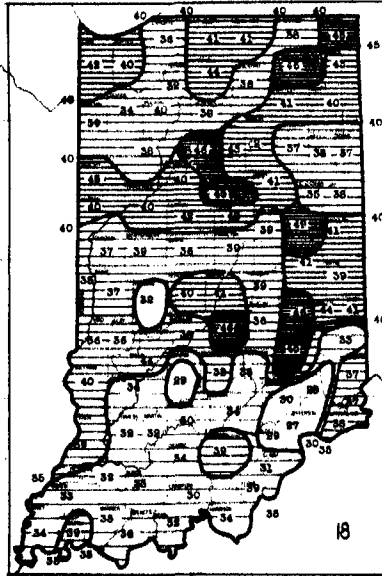


Fig. 18. Oats: Maximum yields, county average, 1923-1934. Bushels per acre.

Conclusions

The distribution of corn, wheat, and oats over Indiana is far from uniform, despite the fact that all three are important in each of the 92 counties. Differences in the proportion of the total land area and of the cropland thus used vary somewhat systematically. Corn occupies nearly or fully one-half of the cropland in all but the most northern elevated and sometimes too cool counties. Wheat occupies a large share of the land of the section with mildest winters because the wheat is winter wheat. Oats are least extensive along the state's southern border where hot weather often comes too early to permit proper development in the spring (the oats are spring sown). Oats are most extensive, in rotation with corn, in the northwestern part of the state.

* Acknowledgments: Assistance in making the numerous calculations was received from three students working for the N. Y. A., especially James Hyndman and Alice Rosenthal. The maps were drafted with the aid of a grant from the Graduate School of Indiana University.

Relative abundance of land devoted to these crops does not correlate closely with average yields. Corn occupies more than half of the cropland in many counties which have a relatively low yield. Similarly, wheat is most extensively sown in one of the less productive areas; conversely, wheat is distinctly less extensive in several counties which have above average yields. Likewise, oats yield better in the eastern than in the western half of the state but are more widely grown in the western half.

The maps of non-average yields throw light upon the contrasts from year to year in the yields and are helpful in understanding certain aspects of the distribution. The distribution of these crops, however, reflects several influences aside from yields, particularly the facts that: (a) no better crop is readily available; (b) the requirements for labor of these crops do not conflict badly, and hence they are often grown so that the farmer is occupied at periods when otherwise there would be little to do; (c) the possibility of receiving a big yield. The maps of maximum yields indicate this inviting possibility.

SECTION ON MATHEMATICS

Chairman: J. E. DOTTERER, Manchester College

The attendance at the Mathematical Section showed a marked increase over that of previous years. Professor P. D. Edwards, of Ball State Teachers College, was elected chairman for 1939.

ABSTRACTS

Invariant subspaces lying in algebraic hypersurfaces of a certain class. D. R. SHREVE, Purdue University.—The paper considers a class of algebraic hypersurfaces representing a generalization of the Clebsch Diagonal Surface and the Segre Cubic Variety. The subspaces discussed are generalizations of the 15 diagonal lines and the 15 planes, respectively lying in these two surfaces. The treatment is algebraic.

Concerning an equality of Landau. A. C. SCHAEFFER and R. J. DUFFIN, Purdue University.—A theorem of Landau relates the bound of a function and the bound of its first two derivatives. It is shown here how inequalities of this type may be sharpened.

Entire functions of exponential type. R. J. DUFFIN and A. C. SCHAEFFER, Purdue University.—Suppose $f(z)$ is an entire function of exponential type. A sufficient condition that $f(z)$ be bounded for real values of z is found.

On flat-sphere geometry. R. H. DOWNING, Purdue University.—In previous papers a partial development of flat spread-sphere geometry in non-Euclidean odd dimensional space has been given. This paper is concerned principally with the surface elements formed when two flats of $(n-2)/2$ dimensions, which are tangent to the absolute surface, intersect in a line. The corresponding elements in an image space of the same dimensions, obtained under the general flat-sphere transformation, are also discussed.

The most dense lattice-form distribution of congruent convex solids. PAUL M. PEPPER, University of Notre Dame.—Various attempts have been made to find that arrangement or those arrangements of certain simple congruent convex solids for which the ratio of space filled to all space is as great as possible, for example, the densest packing of spheres in space. When the convex solid lacks the complete symmetry of the sphere, this problem becomes most difficult and apparently impossible of solution except in certain special cases. There is, however, a quite similar problem wherein the arrangements considered are limited to those for which corresponding lines in the congruent solids are kept parallel. This paper concerns itself with the results which have been obtained for such homothetic arrangements.

Note on Linkages

M. H. AHRENDT, Ball State Teachers College

The article "Linkages", by Mr. Hilsenrath, in the October 1937 issue of the *Mathematics Teacher*, is one of special interest since it deals with a subject not ordinarily emphasized in mathematics courses. It opens a new and interesting study to the student with ramifications carrying over into many related fields of practical and theoretical work. The article is of greatest interest if the reader actually constructs the linkages described and observes their operation. The construction of these linkages, however, presents some problems because of a few slight inaccuracies and omissions in the article.

The most serious omission appears to occur in the discussion of the Peaucellier Conicograph. It is stated in the article that when the length of the

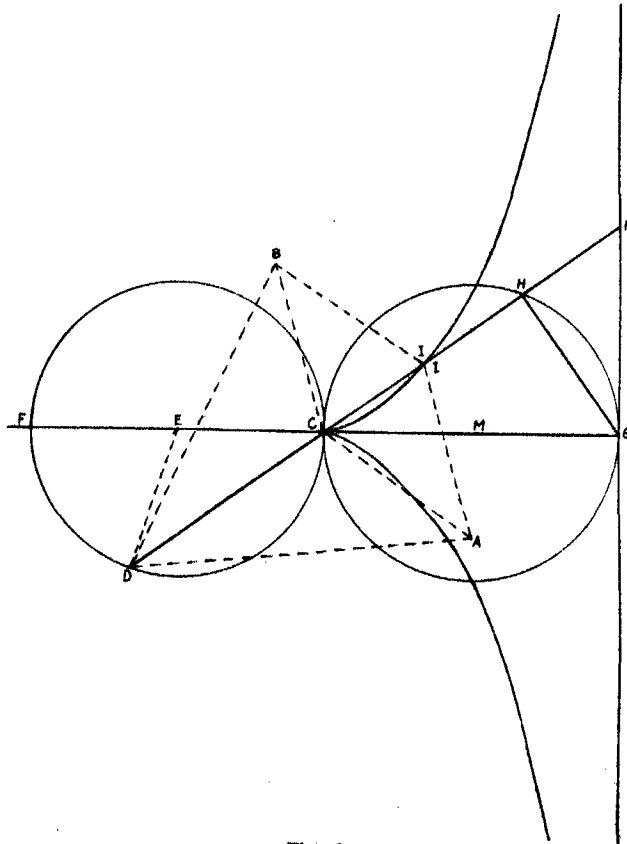


Fig. 1.

radius bar ED is equal to the distance between E and C , then the curve described by I is a Cissoid of Diocles. This is a necessary but not a sufficient condition. Evidently there are an infinite number of positions of E that will enable us to have a radius bar $ED=EC$ (Fig. 1), but in only one of these positions will the cissoid be drawn. The condition that Mr. Hilsenrath has omitted is this:

$$EC = \frac{1}{2} \sqrt{DA^2 - AI^2}$$

As pointed out by Mr. Hilsenrath, the most important property of the Peaucellier Cell (used in this linkage with C as the fixed point instead of D) is that the product $DC \cdot DI = \overline{DA}^2 - \overline{AI}^2 =$ a constant. When the rhombus is collapsed so that C and I coincide, then we readily see that

$$(1) \quad DC \cdot DI = \overline{DC}^2 = \overline{FC}^2.$$

FC then equals $2EC$, and is the diameter of the circle which the point D must follow if the linkage is to draw the cissoid.

Now let another circle with center M be drawn tangent to the first circle at C and with diameter $CG=FC$. Then

$$CH = DC.$$

$$\text{Also} \quad DI = DC + CI.$$

Substituting these values in equation (1) we get

$$(2) \quad CH(CH + CI) = \overline{CG}^2.$$

The question now is, does this last equation satisfy the requirements of the cissoid? Let GK be tangent to the circle at G . Lay off CI' equal to HK . Then by definition the locus of the point I' is a cissoid. By using the triangles CHG and CKG , we note the following facts:

$$\angle HCG = \angle KCG$$

$$\angle CHG = \angle CGK$$

$$\therefore \triangle CHG \sim \triangle CKG$$

$$\therefore \frac{CH}{CG} = \frac{CG}{CK}$$

$$\text{or} \quad CH \cdot CK = \overline{CG}^2.$$

$$\text{But } CK = CH + HK = CH + CI'$$

$$(3) \quad \therefore CH(CH + CI') = \overline{CG}^2.$$

From a comparison of equations (2) and (3) it is evident that I and I' must be the same point, and, therefore, when the linkage is deformed, the point I describes the cissoid.

The discussion of Bricard's Straight-Line Motion also appears to contain some slight inaccuracies. The article states that the length $DB=EC=\frac{a^2}{b}$, and that $DE=\frac{ac}{b}$. But these two conditions are evidently impossible from the

appearance of the linkage and they do not seem to fit the proof needed to establish the theory of the instrument. The correct ratios appear to be these:

$$DB=EC=\frac{b^2}{a}, DE=\frac{bc}{a}.$$

Mr. Hilsenrath also states that the proof for this linkage is based on the theorem that a straight line is the locus of a point which moves so that the difference between the squares of its distances from two fixed points is a constant. The theorem best applied here, however, seems to be a much simpler

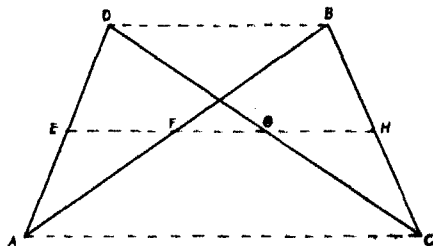


Fig. 2.

one from elementary geometry, namely: The locus of a point equidistant from two fixed points is a straight line which is the perpendicular bisector of the line joining the fixed points. Using this theorem and the ratios given above, the proof for this linkage is quite simple. By drawing the lines FA , DA , etc., we form triangles. It may then be proved in several ways, using congruency or similarity of triangles that $FA = AG$. According to the above theorem, then, the locus of A is a straight line.

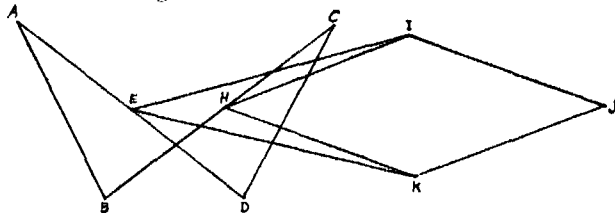


Fig. 3

The Peaucellier Cell is of interest, of course, primarily because it was the first known means of drawing a straight line without the use of a straight edge. The Cell, however, demonstrates so effectively the basic facts of the geometry of inversion that one seems to be wasting a valuable opportunity if he does not construct this linkage so as to make it do more than merely illustrate the straight line. After we have constructed our Cell, then the radius of the circle

of inversion of the Cell is $r = \sqrt{DA \cdot AI}$. This circle may be drawn on the board, and it helps immeasurably in understanding the definition of inversion. Now if we let C or I follow a straight line through D , it becomes evident that any line through the center of inversion is its own inverse. As indicated by Mr. Hilsenrath, a circle through D inverts into a straight line, and a circle not through D inverts into a circle. It is possible, however, to fix the center and radius of this second circle so that both C and I describe complete circles instead of arcs, and this illustrates the theorem vividly. Also it is worth while to arrange that C can draw still a third circle orthogonal to the circle of inversion. Then we note that I follows the same circle; that is, a circle orthogonal to the circle of inversion is its own inverse.

As Mr. Hilsenrath effectively points out, the nine linkages described in his article do not exhaust the subject of linkages. There are a number of other linkages which are sufficiently simple that they might well be added to a collection. Two of these are here described.

It is interesting to note that the Peaucellier Cell is not the only instrument which has the property that the product of the distances of two points from a

third point is a constant. A simpler arrangement is the invensor by Hart illustrated in Figure 2. $ABCD$ is a contra-parallelogram and E, F, G , and H are the mid-points of the sides. Now it is evident from the figure that:

$$EG = FH = \frac{1}{2}AC$$

$$EF = GH = \frac{1}{2}DB$$

It is also evident that A, D, B , and C are concyclic. Therefore, by Ptolemy's theorem,

$$AC \cdot DB + AD \cdot BC = AB \cdot DC$$

But

$$AD = BC \text{ and } AB = DC$$

$$\therefore AC \cdot DB = \overline{AB}^2 - \overline{AD}^2$$

$$\frac{1}{2}AC \cdot \frac{1}{2}DB = \frac{1}{4}(\overline{AB}^2 - \overline{AD}^2)$$

$$\therefore EG \cdot EF = \frac{1}{4}(\overline{AB}^2 - \overline{AD}^2) = \text{a constant}$$

Therefore, if we fix the point E , and F describes a circle through E , then G draws a straight line. That is, exactly the same things that are accomplished by the Peaucellier Cell are also accomplished by this instrument. It is not actually necessary that E, F, G , and H be the mid-points of the sides of the contra-parallelogram. It is only necessary that they lie on a straight line parallel to AC .

An interesting variation of the above linkage is had by fixing the side AD and letting H be the marking point. A variety of curves can then be drawn, depending on the ratio between the sides AD and AB . If we now attach a Peaucellier Cell to the linkage so that the point connecting the long sides of the Cell is fixed at E and the inner point of the rhombus is attached to H , then the outer point of the rhombus evidently draws the inverse of the curve described by H . (As shown above, a second contra-parallelogram could be used instead of the Cell with the same results.) A very interesting special case of this linkage is represented in Figure 3. Let the contra-parallelogram be constructed so that $AD : AB :: \sqrt{2} : 1$. AD thus becomes the long side, and E and H are the mid-points of AD and BC respectively. Let AD be the fixed side. It can be proved by analytical geometry that when this linkage is deformed the locus of H is a lemniscate. Now if a Peaucellier Cell is attached to the points E and H , then J describes the inverse of the lemniscate. That is, J describes an equilateral hyperbola.

The Solution of Bernoulli's Differential Equation by Means of Integrating Factors

WILL E. EDINGTON, DePauw University

The solution of differential equations by means of integrating factors is seldom treated very satisfactorily in textbooks for beginners. The probable reason is that the theoretical development of integrating factors involves a linear partial differential equation. However, students beginning differential equations are, or should be, familiar with elementary partial differentiation, and this assumption will be made in the developments given here. The purpose of this paper is to point out the unity of method and insight into the nature of integrating factors that may be obtained by elementary methods and to secure the solution of Bernoulli's differential equation by means of an integrating factor as a fine illustration of the method.

The usual form of the first order differential equation is

$$Mdx + Ndy = 0, \quad (1)$$

where M and N are functions of either x or y or both. In general the equation is not exact, and, although theoretically the number of integrating factors is infinite, the determination of even one such factor is frequently beyond the powers of the beginner, even if considered practicable. However, suppose $Z(x, y)$ to be an integrating factor of $Mdx + Ndy = 0$. Then

$$ZMdx + ZNdy = 0 \quad (2)$$

is exact, and the condition for exactness

$$\frac{\partial(ZM)}{\partial y} = \frac{\partial(ZN)}{\partial x} \quad (3)$$

is satisfied and one readily obtains

$$Z \left(\frac{\partial M}{\partial y} - \frac{\partial N}{\partial x} \right) = N \frac{\partial Z}{\partial x} - M \frac{\partial Z}{\partial y}$$

which is of the form $Pp + Qq = R$, the first order partial differential equation.

By assuming Z to be a function of x only, or of y only, or of the form $e^{f(x)}$ or $e^{f(y)}$, one obtains the usual special forms of integrating factors. Thus, for example, consider the linear differential equation $dy + (Py - Q)dx = 0$, where P and Q are functions of x only. Multiplying by Z , one has $Zdy + Z(Py - Q)dx = 0$, which is now exact, and, because the equation is exact, equation (3) becomes

$$\frac{\partial Z}{\partial x} = \frac{\partial Z}{\partial y} (Py - Q) + PZ.$$

If now Z is assumed to be a function of x only, one has $dZ/Z = Pdx$, whence $Z = e^{\int P dx}$, the well known form of the integrating factor. As another illustration consider the equation $y(2xy + e^x)dx - e^x dy = 0$. Since y appears to a higher power than the first and since e^x appears, assume $Z = e^{f(x)} y^m$. Then

$$e^{f(x)} y^m (2xy + e^x) dx - e^{f(x)} x y^m dy = 0$$

is exact, and applying equation (3) and simplifying, one has

$$(m+2)2xy + e^x[m+2+f'(x)] = 0$$

identically, whence $m+2=0$, and $m=-2$, and $f(x)$ is constant. Accordingly $Z=y^{-2}$ is the integrating factor. As another illustration consider the equation

$$x^2y \, dy + (y^2 - x^4)dx = 0.$$

Let $Z = e^{f(x)}y^n$. Then

$$e^{f(x)}y^{n+1}x^2dy + e^{f(x)}(y^{n+2} - x^4y^n)dx = 0$$

is exact and equation (3) becomes, after simplification,

$$y^2\{2x + x^2f'(x) \cdot (n+2)\} + nx^4 = 0.$$

Therefore $n=0$, and $2x + x^2f'(x) - 2 = 0$, whence $f'(x) = 2/x^2 - 2/x$, $f(x) = -2/x - 2 \log x$, and $Z = e^{-2/x - 2 \log x}$.

As a final illustration consider

$$xyt^2(3y \, dx + x \, dy) - (2y \, dx - x \, dy) = 0.$$

Let $Z = x^m y^n$, whence, upon multiplying through by Z , applying equation (3), and simplifying, one has

$$(3n - m + 7)xy^2 - (2n + m + 3) = 0,$$

and $3n - m + 7 = 0$, $2n + m + 3 = 0$. Solving, one finds $m = 1$, $n = -2$, and $Z = x/y^2$.

Bernoulli's equation is

$$dy + (Py - Qy^n)dx = 0,$$

where P and Q are functions of x only. Assume $Z = e^{f(x)}y^k$. Multiplying the equation by Z , applying equation (3) and simplifying, one has

$$f'(x) = k(P - Qy^{n-1}) + P - nQy^{n-1}.$$

Separating the variables,

$$[(k+1)P - f'(x)]/Q = (k+n)y^{n-1}.$$

The left member of this last equation is a function of x only, and the right member is a function of y only. Hence $k+n=0$, whence $k = -n$, and then

$$(1-n)P - f'(x) = 0,$$

whence $f(x) = \int (1-n)Pdx$, and $Z = y^{-n}e^{\int (1-n)Pdx}$. Thus one may write down the integrating factor immediately whereas the usual method of solution is to make a substitution that will reduce the equation to the linear form.

Symmetric Jacobi Polynomials

MAJOR ALLEN P. COWGILL, U. S. Army, Retired,
Syracuse University

1. Introduction. It is felt advisable to make more readily available the formulas one finds necessary in working with series of symmetric Jacobi polynomials. These polynomials are denoted by $F(n+p, -n, (p+1)/2, (1-x)/2)$,

$G_n(p, (p+1)/2, (1-x)/2)$, $X_n^{p-1/2, p-1/2}(x)$ and, more recently, $X_n^{p-1/2}(x)$. In mathematical literature most developments are made with two members of the family, Tschebyscheff (trigonometric) polynomials, $p=0$, and Legendre polynomials, $p=1$. Legendre polynomials are easiest to use. Developments can and should be made for the family rather than particular members in certain cases.

2. History. Gauss¹ was interested in the Hypergeometric Series

$$F(\alpha, \beta, \gamma, x) = 1 + \frac{\alpha \cdot \beta}{1 \cdot \gamma} x + \frac{\alpha(\alpha+1)}{1 \cdot 2} \frac{\beta(\beta+1)}{\gamma(\gamma+1)} x^2 + \dots$$

$$(1) \quad \dots + \frac{\alpha(\alpha+1) \dots (\alpha+k-1)}{1 \cdot 2 \dots k} \cdot \frac{\beta(\beta+1) \dots (\beta+k-1)}{\gamma(\gamma+1) \dots (\gamma+k-1)} x^k + \dots$$

as the solution of the differential equation

$$(2) \quad x(1-x)y'' + [\gamma - (\alpha + \beta + 1)x]y' - \alpha\beta y = 0.$$

Jacobi² discovered that this series terminates itself if one of the elements α or β , which enter the series symmetrically, is a negative integer. The polynomials are solutions of the differential equation, but can also be obtained by successive differentiation of a function of x .

$$F(\alpha+n, -n, \gamma, x)$$

$$(3) \quad = 1 + \frac{(\alpha+n)(-n)}{1 \cdot \gamma} x + \frac{(\alpha+n)(\alpha+n+1)}{1 \cdot 2} \cdot \frac{(-n)(-n+1)}{\gamma(\gamma+1)} x^2 + \dots$$

$$\dots + \frac{(\alpha+n)(\alpha+n+1) \dots (\alpha+2n-1)}{1 \cdot 2 \cdot 3 \dots n} \cdot \frac{(-n)(-n+1) \dots (-1)}{\gamma(\gamma+1) \dots (\gamma+n-1)} x^n.$$

$$(4) \quad F(\alpha+n, -n, \gamma, x)$$

$$= \frac{x^{1-\gamma}(1-x)^{\gamma-\alpha}}{\gamma(\gamma+1) \dots (\gamma+n-1)} \frac{d^n}{dx^n} x^{n+\gamma-1} (1-x)^{\alpha+n-\gamma}.$$

Darboux³ and Abramescu⁴ wrote extensive articles on Jacobi polynomials. Darboux's article was the source of most of the formulas in this paper. He it

¹Gauss, 1812. *Disquisitiones generales Circa Seriem Infinitam*, Werke, 8:127.

²Crelle's Journal, 1859. 56:149-185.

³Mémoire sur l'approximation des fonctions de très grands nombres. *Journal de Math.* 1878. 4:5-60, 377-418.

⁴Sulle serie di polinomi di una variabile complessa. Le serie di Darboux. *Annali di Matematica.* 31:207-349.

was who first extended the field of orthogonal polynomials from the real axis to the complex plane.

3. Transformation for Symmetric Polynomials. The condition $\alpha - \gamma = \gamma - 1$, where the difference between α and γ is equal to the difference between γ and 1, and the transformation of x to $(1-x)/2$ gives "symmetric" Jacobi polynomials. They cause

1. Alternate coefficients to become zero, thereby eliminating much work in calculations.
2. The recursion formula to include only terms of first degree in n . This was necessary in the proof of Cesàro summability of $\sum_{n=1}^{\infty} n^p X_n$, where p is a positive integer⁵.
3. The range to be $-1 < x < 1$, instead of $0 < x < 1$.

For Tschchebycheff polynomials $\alpha=0$, $\gamma=1/2$, the difference being $1/2$. For Legendre polynomials $\alpha=\gamma=1$, the difference being 0.

There is no reason why α cannot be greater than 1, ie. $\alpha=3$, $\gamma=2$, or $\alpha=5$, $\gamma=3$. The only rigid condition the writer finds is $\alpha > -1$.

4. The Differential Equation. The original hypergeometric differential equation of Gauss (2) is transformed to

$$(5) \quad (1-x^2)X_n'' - [(p+1)x]X_n' + (p+n)nX_n = 0.$$

In modern notation $\alpha=p$ and $\gamma=(p+1)/2$, one choosing any $p > -1$. Unless explicitly stated otherwise the formulas throughout the remainder of the paper, including (5), all contain p , X_n denotes $X_n^{p-1/2}(x)$, and x is confined to the range $-1 < x < 1$.

5. The Recursion Formula. From the recursion formula

$$(6) \quad xX_n = \frac{n+p}{2n+p}X_{n+1} + \frac{n}{2n+p}X_{n-1}$$

one can get any set of polynomials by taking $X_0=1$, $X_1=x$, and assuming a value of $p > -1$.

The polynomials can be obtained from (3) or (4), letting $x=(1-x)/2$, $\alpha=p$ and $\gamma=(p+1)/2$. They are also obtained from the generating function.

6. The Generating Function. Brenke's method⁶ of deriving the generating function is based on the Lagrange expansion formula⁷. Putting the differential equation (5) in the form

$$\frac{1-x^2}{p+1}X_n'' - xX_n' + \frac{p+n}{p+1}nX_n = 0,$$

one substitutes the coefficient of X_n'' for $\phi(y)$, changing x to y , in the equation $y=x+t\phi(y)$ and obtains

$$(a) \quad y = x + t \frac{1-y^2}{p+1}.$$

⁵Cowgill, 1935. On the summability of a certain class of series of Jacobi Polynomials. Bull. Am. Math. Soc. 41: 541-549.

⁶On polynomial solutions of a class of linear differential equations of the second order. Bull. Am. Math. Soc. 38:77-84, 82. 1930.

⁷Goursat-Hedrick, 1904. Mathematical Analysis. Vol. 1, par. 189.

Differentiating partially with respect to x .

$$\frac{\partial y}{\partial x} = 1 + \frac{t}{p+1} (-2y) \frac{\partial y}{\partial x}, \quad \frac{\partial \gamma}{\partial x} = \frac{1}{1 + \frac{2ty}{p+1}}$$

From (u)

$$\frac{ty^2}{p+1} + y - \left(x + \frac{t}{p+1} \right) = 0.$$

Solving by the quadratic formula and

making the transformation $t = -\frac{p+1}{2}t$,

$$y = \frac{-1 \pm \sqrt{1-2tx+t^2}}{-t}.$$

$$\frac{\partial y}{\partial x} = \frac{1}{1-ty} = \frac{1}{\sqrt{1-2tx+t^2}}.$$

Substituting the "characteristic function"

$$\rho = (p+1)(1-\lambda^2)^{\frac{p-1}{2}}$$

in Brenke's expression for the generating function,

$$\begin{aligned} (7) \quad \psi(x, t) &= \frac{\rho(y)}{\rho(x)} \frac{\partial y}{\partial x} = \frac{(p+1)(1-y^2)^{\frac{p-1}{2}}}{(p+1)(1-\lambda^2)^{\frac{p-1}{2}}} \frac{1}{\sqrt{1-2tx+t^2}} \\ &= \left[\frac{t^2 - (1-2\sqrt{1-2tx+t^2} + 1-2tx+t^2)}{t^2(1-\lambda^2)} \right]^{\frac{p-1}{2}} \frac{1}{\sqrt{1-2tx+t^2}} \\ &= \left[\frac{4}{(1-\lambda^2)(2tx-2+2\sqrt{1-2tx+t^2})} \right]^{\frac{p-1}{2}} \\ &\quad \frac{(2t)^{p-1} \sqrt{1-2tx+t^2}}{(2t)^{p-1} \sqrt{1-2tx+t^2}} \\ &= \sum_{r=0}^{\infty} a_r X_r t^r, \end{aligned}$$

where

$$a_n = \frac{(p+1)(p+3) \dots (p+2n-1)}{2^n n!}$$

$$= \frac{\left[\left(\frac{(p+1)}{2} + n \right) \right]}{\left[\left(\frac{(p+1)}{2} \right) \right] (n+1)} = 0 \binom{\frac{p-1}{2}}{n}.$$

$$X_n = 0 \binom{-\frac{p}{2}}{n}, \text{ so } a_n X_n = 0 \binom{-1}{n-2}$$

$$X_n(1) = 1, X_n(-1) = (-1)^{n-2}$$

*This is shown by using equations (1) and (4), Darboux, loc. cit., p. 377, and making the transformation $x = (1-\xi)/2$, $x=0$ corresponding to $\xi=1$ and $x=1$ corresponding to $\xi=-1$, $\alpha-\gamma=\gamma-1$.

One also has the relation*

$$(8) \quad \sum_{r=0}^{\infty} \frac{[(r+p)]}{[(p)][(r+1)]} X_r t^r = \frac{1}{(1-2tx+t^2)^{\frac{p}{2}}} \quad (0 < t < 1).$$

Differentiating both sides of (8), multiplying throughout by $2t$ and adding to (8), one gets

$$\sum_{r=0}^{\infty} \frac{[(r+p)]}{[(p)][(r+1)]} (2r+p) X_r t^r = \frac{p(1-t^2)}{(1-2tx+t^2)^{\frac{p}{2}+1}}$$

which one can write in the form

$$(9) \quad \sum_{r=0}^{\infty} \frac{[(r+p)]}{[(p)][(r+1)]} (2r+p) X_r t^r = \frac{[(p+1)]}{[(p)]} \frac{1-t^2}{1-2tx+t^2}.$$

Let $p=0$ and one obtains the special generating function for the Tschebychef polynomials

$$(10) \quad \sum_{r=0}^{\infty} 2[X_r]^{\frac{1}{2}}(x) t^r = \frac{1-t^2}{1-2tx+t^2}, \text{ or}$$

$$\sum_{r=0}^{\infty} T_r(x) (2t)^r = \frac{1-t^2}{1-2tx+t^2} \text{ where } T_n(x) = \frac{1}{2^{n-1}} [X_n]^{\frac{1}{2}}(x).$$

One can now see that series (9) is the Cauchy product of series (8) and series (10), as well as being the right hand member of the Christoffel-Darboux identity

$$(11) \quad \frac{[(n+p)]}{[(p)][(n+1)]} \frac{X_{n+1} - X_n}{x-1}$$

$$= \sum_{r=0}^n \frac{[(r+p)]}{[(p)][(r+1)]} (2r+p) X_r, \text{ when } t=1.$$

7. Symmetric Jacobi Polynomials.

$p=0$, Tschebychef Polynomials.

$X_0(x) = 1$	$X_0(\cos \theta) = 1$
$X_1(x) = x$	$X_1(\cos \theta) = \cos \theta$
$X_2(x) = 2x^2 - 1$	$X_2(\cos \theta) = \cos 2\theta$
$X_3(x) = 4x^3 - 3x$	$X_3(\cos \theta) = \cos 3\theta$
$X_4(x) = 8x^4 - 8x^2 + 1$	$X_4(\cos \theta) = \cos 4\theta$

$p=1/2$.

$X_0 = 1$	$X_2 = 3(x^2 - \frac{2}{3})$
$X_1 = x$	$X_4 = \frac{1}{7}(39x^4 - 36x^2 + 4)$
$X_2 = \frac{5}{2}(x^2 - \frac{2}{3})$	

*Cowgill, *loc. cit.*, pp. 543 and 545.

$p=1$. Legendre Polynomials.

$$X_0=1$$

$$X_2=\frac{1}{2}(5x^2-3x)$$

$$X_1=x$$

$$X_4=\frac{1}{8}(35x^4-30x^2+3)$$

$$X_2=\frac{1}{2}(3x^2-1)$$

$p=3$.

$$X_0=1$$

$$X_3=\frac{1}{4}(7x^3-3x)$$

$$X_1=x$$

$$X_4=\frac{1}{8}(21x^4-14x^2+1)$$

$$X_2=\frac{1}{4}(5x^2-1)$$

$p=5$.

$$X_0=1$$

$$X_3=\frac{1}{2}(3x^3-x)$$

$$X_1=x$$

$$X_4=\frac{1}{16}(33x^4-18x^2+1)$$

$$X_2=\frac{1}{6}(7x^2-1)$$

8. **The Orthogonality Property.** In expanding any function of x into an infinite series of symmetric Jacobi polynomials it is necessary that the polynomials have the orthogonality property expressed by

$$(12) \quad \int_{-1}^1 \rho X_m X_n dx = \begin{cases} 0, & m \text{ not equal to } n \\ J_n, & m=n, \end{cases}$$

so that the coefficients can be determined.

Brenke's¹⁰ condition for orthogonality will hold with the polynomial solutions of (5).

The derivation of the characteristic function ρ and Darboux's value of the constant J_n are best explained in detail.

9. **The Characteristic Function ρ .** To explain the derivation of the characteristic function ρ one assumes the differential equation

$$(b) \quad rX_n'' + sX_n' + t_nX_n = 0, \quad t_n \text{ a function of } n.$$

Multiplying (b) by ρ so as to make it "self adjoint", one has

$$(c) \quad \rho rX_n'' + \rho sX_n' + \rho t_nX_n = 0, \text{ where}$$

$$(d) \quad \frac{d}{dx} \rho r = \rho s = \rho' r + \rho r'. \quad (b) \text{ can now be written}$$

$$(e) \quad \frac{d}{dx} (\rho r X_n') + \rho t_n X_n = 0.$$

$$\text{From (d) } \rho' r = \rho(s - r'). \quad \frac{\rho'}{\rho} = \frac{s - r'}{r} = \frac{s}{r} - \frac{r'}{r}.$$

Multiplying by dx and integrating

$$\int \frac{\rho'}{\rho} dx = \int \frac{s}{r} dx - \int \frac{r'}{r} dx,$$

¹⁰Brenke, *loc. cit.*, Case 1, pp. 72-79.

$$\log \rho = \int \frac{s}{r} dx - \log r ,$$

$$\log \rho + \log r = \log \rho r = \int \frac{s}{r} dx ,$$

$$\rho r = e^{\int \frac{s}{r} dx} \quad \text{or} \quad \rho = \frac{1}{r} e^{\int \frac{s}{r} dx}$$

Taking the differential equation (5) in the form

$$\frac{1-x^2}{p+1} X_n'' - x X_n' + \frac{(p+n)n}{(p+1)} X_n = 0$$

and comparing it to (b)

$$r = \frac{1-x^2}{p+1} \text{ and } s = -x, \text{ so}$$

$$(13) \quad \rho = \frac{p+1}{1-x^2} e^{\int \frac{-x dx}{1-x^2}} = \frac{p+1}{1-x^2} (1-x^2)^{\frac{p+1}{2}}.$$

Write the "self adjoint" equations for X_n and X_m .

$$(f) \quad \frac{d}{dx}(\rho r X_n') + \rho t_n X_n = 0$$

$$(g) \quad \frac{d}{dx}(\rho r X_m') + \rho t_m X_m = 0.$$

Multiply (f) by X_m and (g) by X_n . Subtracting, multiplying by dx and integrating¹¹ one gets

$$(t_m - t_n) \int_{-1}^1 \rho X_m X_n dx = \int_{-1}^1 X_m \frac{d}{dx} \left(\rho r \frac{dX_n}{dx} \right) dx - \int_{-1}^1 X_n \frac{d}{dx} \left(\rho r \frac{dX_m}{dx} \right) dx.$$

Integrating by parts

$$(t_m - t_n) \int_{-1}^1 \rho X_m X_n dx = \left[X_m \left(\rho r \frac{dX_n}{dx} \right) - X_n \left(\rho r \frac{dX_m}{dx} \right) \right]_{-1}^1 - \int_{-1}^1 \rho r \frac{dX_n}{dx} \frac{dX_m}{dx} dx + \int_{-1}^1 \rho r \frac{dX_m}{dx} \frac{dX_n}{dx} dx.$$

As ρr contains the factor $(1-x^2)$ the non-integral term is 0 and $\int_{-1}^1 \rho X_m X_n dx = 0$ unless $m=n$. This last equation expresses the orthogonality property (12).

10. Derivation of J_n . The writer found it necessary to solve for J_n with the notation of Darboux and general Jacobi polynomials. From Darboux¹² "One has also

$$J_n = \int_0^1 x^{\gamma-1} (1-x)^{\alpha-\gamma} X_n^2 dx \\ = \frac{[(n+1) \Gamma^2(\gamma) \Gamma(\alpha+n-\gamma+1)]}{(2n+\alpha) \Gamma(\alpha+n) \Gamma(\gamma+n)}.$$

¹¹Byerly, Fourier's Series. Par. 91, p. 171.

¹²Loc. cit., (44), p. 46 and (13), p. 22.

and

$$\begin{aligned} X_n &= F(\alpha+n, -n, \gamma, x) \\ &= \frac{x^{1-\gamma} (1-x)^{\gamma-\alpha}}{\gamma(\gamma+1) \dots (\gamma+n-1)} \frac{d^n}{dx^n} x^{n+\gamma-1} (1-x)^{\alpha+n-\gamma}, \\ [(\gamma+n) &= (\gamma+n-1) (\gamma+n-2) \dots (\gamma+1) \gamma], \\ \text{so } \gamma(\gamma+1) &\dots (\gamma+n-1) = \frac{[(\gamma+n)]}{[(\gamma)]}. \end{aligned}$$

$$J_n = \frac{[(\gamma)]}{[(\gamma+n)]} \int_0^1 [X_n] \left[\frac{d^n}{dx^n} x^{n+\gamma-1} (1-x)^{\alpha+n-\gamma} \right] dx.$$

One applies integration by parts n times, where $\int u dv = uv - \int v du$, letting the polynomial always be u and the derivative and dx be dv . The uv term is always zero with the limits 0 and 1, as it always contains the terms x and $(1-x)$ to some power. Differentiating X_n , (3), n times one finishes with the coefficient of x^n multiplied by $n!$, so

$$\begin{aligned} \frac{d^n}{dx^n} X_n &= [(n+1)] \frac{[(\alpha+2n)]}{[(n+1)] [(\alpha+n)]} \frac{(-1)^n [(n+1)] [(\gamma)]}{[(\gamma+n)]} \\ &= (-1)^n \frac{[(\alpha+2n)] [(n+1)] [(\gamma)]}{[(\alpha+n)] [(\gamma+n)]}. \end{aligned}$$

After n integrations by parts

$$J_n = \frac{[(\gamma)]}{[(\gamma+n)]} (-1)^{2n} \frac{[(\alpha+2n)] [(n+1)] [(\gamma)]}{[(\alpha+n)] [(\gamma+n)]} \int_0^1 x^{n+\gamma-1} (1-x)^{\alpha+n-\gamma} dx.$$

$$B(m, n) = \int_0^1 x^{m-1} (1-x)^{n-1} dx = \frac{[(m)] [(n)]}{[(m+n)]},$$

$$\text{so } \int_0^1 x^{n+\gamma-1} (1-x)^{\alpha+n-\gamma} dx = \frac{[(\gamma+n)] [(\alpha+n-\gamma+1)]}{[(2n+\alpha+1)]}.$$

$$J_n = \frac{[(n+1)]^2 [(\gamma)] [(\alpha+n-\gamma+1)]}{(2n+\alpha) [(\alpha+n)] [(\gamma+n)]}, \text{ Darboux's result.}$$

Making the transformation to symmetric Jacobi polynomials

$$\begin{aligned} (14) \quad J_n &= \int_{-1}^1 (p+1) (1-x^2)^{\frac{p-1}{2}} \left[X_n^{\frac{p-1}{2}}(x) \right]^2 dx \\ &= \frac{2^p (p+1) [(n+1)] \left[\left(\frac{p-1}{2} \right) \right]}{(2n+p) [(p+n)]} 14. \end{aligned}$$

11. The Derivative Form. Transforming (4) one obtains

$$(15) \quad X_n = \frac{(-1)^n (1-x^2)^{\frac{1-p}{2}}}{(p+1) (p+3) \dots (p+2n-1)} \frac{d^n}{dx^n} \frac{(p+2n-1)}{(1-x^2)^{\frac{p+2n-1}{2}}}.$$

¹¹Woods, Advanced Calculus, p. 166.

¹²See Byerly, loc.cit., par. 89, p. 168, for derivation of J_n for Legendre polynomials.

SECTION ON PHYSICS

Chairman: S. E. ELLIOTT, Butler University

All the papers listed in the program and published in full or in abstract form below were read. The attendance was good. Raymond B. Abbott, of Purdue University, was elected chairman of the section for 1939.

ABSTRACTS

Wave motion demonstration. S. E. ELLIOTT, Butler University.—The machine is designed to aid high school and college students in getting a better understanding of both transverse and longitudinal waves. It shows two transverse waves, traveling in the same or in opposite directions, with the resultants back of them. These waves can have any relative amplitude and wave length, but, as constructed, they are equal in all respects and thus cause standing waves when traveling in opposite directions. The machine also shows a longitudinal wave in which the relative phase of successive particles can be changed, showing longitudinal waves of different length. With additional equipment, standing longitudinal waves can also be shown. All the waves can be made to travel as slowly as desired.

On the thermoelastic properties and on the equation of state of rubber. F. E. DART and E. GUTH, University of Notre Dame.—The high reversible elasticity and the anomalous thermoelastic behavior of rubber are explained qualitatively and to a large extent also quantitatively in terms of the molecular structure of rubber without making any arbitrary assumptions. Rubber consists of long chain molecules, which, in the unstretched state, are in a more or less curved form due to the possibility of free rotations around a single C-C bond in the single chains. This curved form is the most probable one according to the statistical interpretation of the second law of thermodynamics. If a stress be applied, these curved molecules will be stretched, thus giving a transition to a less probable state. When the stress is released, the thermal agitation causes a retraction. Rubber elasticity is then analogous to the elasticity of a gas or a liquid. In order to test and develop further this theory, experimental work on the physical properties of natural and synthetic rubber was begun. Our first objective was to obtain the thermal equation of state of rubber, i. e., the dependency of the stress upon temperature and extension. The thermal state equation together with the so-called caloric state equation, i. e., the dependency of the specific heat at constant extension upon the temperature and the extension, determines completely the thermodynamics of stretched rubber. It gives the free energy of stretched rubber. A

stress-strain apparatus allowing stretching and retracting rubber with a constant speed was used in some preliminary work with different types of rubber. Diagrams are presented which show the reproducibility of the data obtained and the change of the extension-retraction curves, i. e., of the hysteresis hoops, with the number of extensions and temperature. Diagrams for equations of state are shown. For elastically normal substances, e. g., steel, wood, etc., the stress decreases with rising temperature. This shows that in these cases the great elastic force between the atoms or molecules causes the retraction for rubber. This force-mechanism of elasticity is present also. However, in addition to the force-mechanism the statistical mechanism described above contributes to the retraction and can even predominate giving rise to an equation of state according to which the stress increases with rising temperature just as this is the case for a gas.

Proton diffraction by vapors. H. J. YEARIAN, Purdue University.—The methods of electron diffraction in molecular structure analysis are inapplicable to molecules of low molecular weight because of the low scattering power of such molecules. Since protons should be scattered much more strongly than electrons, extensive experiments have been made to investigate their diffraction by molecular vapors. It was found possible to obtain diffraction patterns of carbon tetrachloride but not of lighter molecules. The apparatus used, difficulties encountered, and principal results are discussed.

A fundamental error in wave motion. R. R. RAMSEY, Indiana University.—Since it has been shown that *damped wave* oscillators and *continuous wave* oscillators apparently do not give the same kind of resonance curves, detailed studies have been made of the modes of vibration. When the coupling is close, there are two possible modes of vibration, one stable and the other metastable. The circuit does not oscillate in these two modes at the same time. When the oscillator is started, it always assumes the stable mode; the metastable mode is secured by gradually changing the constants of the circuit. It is shown that a damped wave oscillator produces a band of frequencies, and, since a closely coupled circuit is in resonance for two peak responses, the circuit picks out the two frequencies. This is the reason why it was concluded in the old spark days that coupled circuits produce two frequencies. It is proved definitely that coupled circuits do not produce or manufacture two frequencies. This correction should be applied to modern physics.

Modulation a linear process. R. R. RAMSEY, Indiana University.—It seems to be the opinion of many that modulation is a non-linear process, but it is pointed out that, if the adjustments of the circuits are right, it is a linear process. In a class C amplifier, in which the radio frequency current is directly proportional to the plate potential, we have the products of sine terms, with side bands and no harmonics, when the amplifier is modulated. Modulation can also be produced by non-linear addition, but this always produces harmonics and other undesirable combinations.

The scattering of barytrons. J. F. CARLSON, Purdue University.—The increasing experimental evidence for the existence of a "heavy electron" gives importance to the theoretical calculations of its interaction with matter and radiation based on the various models which have been suggested. Since the explanation of nuclear forces by means of the barytron is best given by the description which uses a vector wave function, the calculations for this model are especially important. Only the elastic scattering will be considered. Elastic scattering may take place by two processes, (a) by the absorption and re-emission of barytrons by nuclear particles, analogous to the Compton scattering of light, (b) by the Coulomb field of a nucleus. The first process has been investigated by Heitler, and the second is considered here. The results show that for low energies the Coulomb scattering is more important than the first process and that for high energies the reverse is true. There are also polarization effects present in the scattering which may be of importance for particles traversing the atmosphere.

The Purdue cyclotron. W. J. HENDERSON, Purdue University.—Since the last report to the Indiana Academy of Science the construction of the Purdue cyclotron has been completed. This paper is a description of the construction of the accelerating chamber and of the adjustments of the magnetic field and oscillator. The magnetic field has been corrected by a special ring shim so that the field is now uniform over an area of 40 cm. in diameter. The oscillator and magnetic fields are tuned at present to produce 4.4 million volt protons, 8.8 million volt deuterons, or 17.6 million volt particles. Experiments are being conducted to adapt the low voltage arc as a source of ions.

On the interaction of high energy electrons with nuclei. EUGENE GUTH, University of Notre Dame.—Interaction of high energy electrons with nuclei can give rise to scattering, pair production, and disintegration phenomena. From the theoretical point of view, the pair production and radiation are equivalent processes. The cross-section for both phenomena can be obtained from the same expression by changing simply the variables. Whereas, the experimental results on radiation of electrons above one million electron volts are in accordance with the theories at least in the order of magnitude, the experiments of pair production are contradictory with each other and with the theory also. Nuclei can be disintegrated by fast electrons provided that the energy of the electrons exceeds the binding energy of one of the constituents of the nucleus. The threshold value is only for the beryllium nucleus and the deuteron within the range of electron energies available at present experimentally. The cross-section for the disintegration of the beryllium nucleus was calculated by using both the method of Moller and that of the Fourier analysis. The threshold energy is according to the experiments with gamma rays on the photo-disintegration of beryllium 1.7 MEV. This represents the lowest known threshold energy for any nucleus. The cross-section for the disintegration of Be_4^9 into Be_4^8 and a neutron is according to a very conservative estimate of the quantities entering into the formula 10^{-31} cm^2 . This is

a thousand times smaller than the observed cross-section for the disintegration of beryllium with gamma rays. Experiments to detect an electroneutronic disintegration are in process using electrostatic generators. High energy electrons can also be used for the excitation of nuclei and for the sounding of the nucleus in analogy to the measurement of molecular distances by X-rays and low energy electrons.

On the preparation of metal surfaces for electron emission studies. EDWARD A. COOMES, University of Notre Dame.—The most important requirement imposed upon filaments used in electron emission studies is that they be absolutely gas-free as far as the surface is concerned. Two methods have been generally employed for obtaining clean surfaces. The first, commonly employed for highly refractory metals, consists simply in heating at high temperatures for long periods of time to rid the body of the filament of absorbed gases and a final high temperature flash to clean the surface of gases adsorbed to it. The second method, used mostly for metals of low melting point, consists in building up the working surface by evaporating onto a base filament from a source of the desired metal. Experimental data in general have shown both of these methods to be inadequate for quantitative studies. A further method is offered in which a working surface is built up on a well out-gassed filament by evaporating, not from the supposedly pure metal but from a source containing the metal in chemical combination. It has been found, at least in the case of thorium, that such a source can be made to give off the pure metal and hold the gas apparently in solution in the body of the filament if the proper cycle is followed. This is confirmed by experimental work on secondary emission of electrons from a tungsten surface, coated with thorium evaporated from thoriated tungsten.

Continuous Spectra of H_2 and D_2 . HUBERT M. JAMES, Purdue University.—Complete theoretical computations have been made of the continuous spectra of H_2 and D_2 arising from transitions from the lower vibrational levels of the $1s\sigma 2s\sigma \ ^3\Sigma_u$ state to the unstable $1s\sigma 2p\sigma \ ^3\Sigma_u$ state. Spectra have been determined for transitions from each of the vibrational levels separately, and the first reported computations on absolute mean lives of molecular vibrational levels have been made. Relative probabilities of excitation from the ground states of the molecules by electron impact have been estimated, and intensities in the spectra excited by electron impact have been computed for a range of energies of the electrons. The spectra of H_2 and D_2 have the same qualitative character but quite appreciable quantitative differences. In the case of H_2 there is sharp disagreement of the results with the observations of Smith. This apparently arises from errors in Smith's intensity standard and emphasizes the need of a more satisfactory intensity standard in the ultraviolet. Agreement with the observations of Finkelberg and Weizel is obtained.

On the van der Waals energy of two beryllium atoms. JULIAN K. KNIPP, Purdue University.—The first term in the expansion of the electrostatic interaction of two neutral atoms in powers of $1/R$, where

R is the interatomic distance, is the term in $1/R^3$, the dipole-dipole term. Since isolated atoms have no dipole moments, the effect of this term on the energy of the system is only through the mutual polarization of the atoms, a second order effect first treated quantum mechanically by Wang. The constant u in the van der Waals energy, $-u/R^6$, has been calculated for two beryllium atoms using the Hartree-Fock model for the atoms. Perturbation methods are used based on the complete set of solutions of the Fock single-electron differential-integral equation. These solutions satisfy sum rules which, because of the integral part of the Fock equation, are not in general given by the usual relations. Lower bounds to the interaction expression are obtained by the application of the Schwarz inequality and the use of the sum rules derived. In this way u for two beryllium atoms is found to be about $222 \cdot 10^{-40}$ erg cm⁶.

The fashioning of perfect ellipsoidal boulders by glacial action. OLIVER E. GLENN, Lansdowne, Pa.—The general principles of the flow of a viscous stream, such as the lower layer of a glacier, are obtained by applying mathematics to some types of boulders which are shaped by the action of streams heavily charged with siliceous sand. In upper New England there have been found numerous granite boulders which are mathematically perfect ellipsoids, each with the principal axes different in length; and many of the hills of Maine are hyperboloids. From these facts the law of flow of the stream which fashioned the boulders is derived, appearing in a typical case as follows:

$$F = \text{Speed} = \frac{S\sqrt{(a^4 \sin^2 \theta + b^4 \cos^2 \theta)}}{b^2 \cos^3 \theta}.$$

The speed at a given level is thus a function of θ with two parameters, S and a/b , and it may further be generalized to contain three parameters. (The origin of polar coordinates (r, θ) was taken as the center of the conicoid.) Reversing the problem and assuming the law of flow in the form F , the solution of a differential equation of the first order shows that the boulder will be an ellipsoid or hyperboloid. This principle offers an explanation why the Tipton Till Plain is flat while the New England landscape is hilly, as well as a number of other suggestions of possible interest to geologists.

Application of trigonometric interpolation to X-ray analysis. C. LANCZOS and G. C. DANIELSON, Purdue University.—The integral representing the intensity distribution of X-ray diffraction in liquids can be evaluated by the method of trigonometric interpolation instead of approximating the integral by the sum of a large number of terms. This reduces considerably the number of ordinates required in the calculation without decreasing the accuracy. As an example, the diffraction patterns of vitreous selenium and liquid KCl and LiCl, obtained and analyzed by K. Lark-Horovitz and E. P. Miller, have been interpreted. For the curves so far analyzed, 36 ordinates were found to be sufficient. Owing to symmetry properties the Fourier coefficients can be found with a minimum of calculation. This yields directly the value of the distribution function in discrete equidistant points. The

value of the function for any intermediate point may then be determined in a simple manner by pure calculation. The resulting curves agree very closely with those obtained by Lark-Horovitz and Miller.

The resonance processes in the disintegration of Boron by protons. BERNARD WALDMAN, University of Notre Dame.—Using protons of energies from 150 kev to 195 kev, the gamma ray and alpha particle yields from a thick boron target were determined simultaneously. The observed resonances occur at the same voltage, to within 1 kev. Yield curves on the alpha particles alone place the resonance voltage at 165 ± 4 kev. The observed half-breadth of 6 kev can be ascribed to energy fluctuations in the ion beam. The experiments were done at New York University in collaboration with R. Waddel, D. Callihan, and W. A. Schneider.

A device for demonstrating the resultant of two concurrent forces. C. O. PAULEY, Valparaiso H. S.—Demonstration of apparatus.

The trochoid method of magnetic focusing as applied to a study of pair production by electrons. ROBERT L. ANTHONY, University of Notre Dame.—Experimental values of the cross-section for pair production in the field of a nucleus by high speed electrons are in poor agreement at the present time. Skobelzyn and Stepanowa, using a cloud chamber, found a value for this cross-section about one hundred times larger than that for gamma rays of the same energy. Da Silva's work, also done with a cloud chamber, yields a value of 8×10^{-28} cm² for lead—about half as large as the value of Skobelzyn and Stepanowa. Benedetti, using the trochoid method of focusing and counters, and Alichanow and coworkers, using magnetic focusing and counters, decided that the value was much smaller, too small to be detected by their methods. Staub concluded the value could not be greater than that for gamma rays. Later, Monadjemi, using the trochoid method, obtained large values of the order of 10^{-23} cm². Recently work performed by Feather and Dunworth indicates that the larger experimental values may be correct. The majority of these experimental results are much higher than those predicted by theory and seem to indicate that the cross-section is proportional to Z and not to Z^2 . In view of the disagreement between these experimental values, and since a large monochromatic source of high energy electrons is available at Notre Dame, we have decided to attempt a more accurate determination of this cross-section. For this purpose, the trochoid method of focusing will be used. This method is particularly well adapted to the problem since the yield obtained by it is from one hundred to a thousand times larger than that obtainable by ordinary magnetic focusing. The magnet which has been constructed for this purpose and the advantages of the trochoid method are described.

A Method of Measuring the Total Output of Speakers

D. B. GREEN, Ohio University

Routine measurements of speaker output are usually made in a single direction on the axis extending out in front of a speaker. However, the total acoustic output is sometimes desired. Indeed, were it not so hard to obtain, the total output would in most cases be the proper information to publish. In speaker efficiency measurements the total output is required, and in actual practice the listener is seldom in open air, where he would receive the output in a particular direction alone, but he is inside a room, where, by reflection, he is subjected to the total speaker radiation field.

There are several methods for finding this total output. The speaker may be measured out-of-doors by taking the average of a number of measurements on the surface of an imaginary sphere of which the speaker is the center (1). In the reverberation chamber method the speaker is located in a highly reverberant room, and its total output calculated by a single measurement with a microphone placed anywhere in the room on the theory that the acoustic pressure becomes constant regardless of frequency and location in the room (2, 3). Another method is to simulate outdoor conditions by making measurements in a highly absorbing room treated with acoustic materials (4). Bell Telephone laboratories have rotated the microphone at a speed sufficient to eliminate standing waves while making measurements (5). A multiple microphone method employs several microphones placed about the speaker so as to obtain at a single measurement sufficient data to calculate the total output.

In the motional impedance method, the free and blocked impedance of the speaker are found electrically, and the efficiency calculated from these constants (6).

There can be no objection to the outdoor method except its inconvenience. Our experience with the reverberation chamber method shows the presence of standing waves in all enclosures, which shift with changing frequency, rendering the results of no value for showing speaker characteristics. As to sound absorbing rooms, it is very difficult to eliminate reflection even with a foot of hair-felt lining the room. In working with the multiple microphone method, the writer has found that all types of microphones have polarity, so that when connected together they will measure the vector sum of the effective values of the acoustic pressure or velocity at their respective locations and thus give maxima and minima as the frequency is varied, showing a pattern which does not belong to the speaker at all (7). The motional impedance method avoids acoustical measurements but neglects mechanical losses of motion and rates the speaker optimistically.

This paper describes a method of measuring the total output of a speaker which is analogous to the method of measuring the total luminous flux from a lamp by means of a globe photometer. The speaker is placed at the center of a 3-foot globe photometer. A microphone is placed at the small window of the globe and shielded from direct radiation from the speaker so that it receives only sound which has been reflected one or more times from the wall of the globe. A single measurement of the intensity at the window gives a figure which is proportional to the total sound flux emitted by the speaker. The theory may be found in textbooks on illumination (8). The method used to eliminate standing waves in the globe was to wobble the frequency of the oscillator used to drive the speaker, above and below the frequency at which it is set. An analysis was made to determine what variation in frequency was desirable to eliminate the standing waves and yet not be so great as to mask the frequency characteristics of the speaker. The frequency variation necessary to move one loop past the microphone and back was calculated, as this requires the microphone to read the average intensity from loop to loop and should smooth out the pattern.

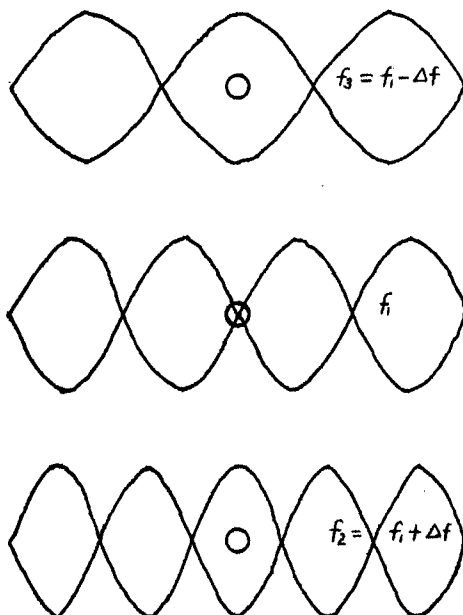


Fig. 1.

In Figure 1 suppose at the middle frequency f_1 there are n_1 half waves in the enclosure. The wavelength $\lambda_1 = \frac{2L}{N_1}$ where L is the length of the enclosure.

$$f_1 = \frac{V}{\lambda_1} \text{ where } V \text{ is the sound velocity, or } f_1 = \frac{Vn_1}{2L}$$

For one more half wave within the globe, $n_2 = n_1 + 1$

$$\lambda_2 = \frac{2L}{n_2} = \frac{2L}{n_1 + 1}$$

$$f_2 = \frac{V(n_1 + 1)}{2L}$$

$$\frac{f_2}{f_1} = \frac{2V(n_1 + 1)L}{2LVn_1} = \frac{n_1 + 1}{n_1} = 1 + \frac{1}{n_1}$$

$$f_2 = f_1 + \frac{f_1}{n_1} \text{ or } \Delta f = \frac{f_1}{n_1} \text{ but } n_1 = \frac{2f_1 L}{V} \text{ hence } \Delta f = \frac{f_1 V}{2f_1 L} = \frac{V}{2L} \text{ a constant.}$$

This shows that to shift the pattern from a node to an antinode in front of the microphone requires a constant frequency increment independent of the original frequency.

Now to see what happens to the pattern when the frequency is decreased by the same increment—

$$f_2 = f_1 + \frac{V}{2L} \text{ and } f_3 = f_1 - \frac{V}{2L}$$

$$\lambda_1 = \frac{V}{f_1}, \lambda_2 = \frac{V}{f_1 + \frac{V}{2L}} = \frac{2LV}{2Lf_1 + V}$$

$$\lambda_3 = \frac{V}{f_1 - \frac{V}{2L}} = \frac{2LV}{2Lf_1 - V}, n_1 = \frac{2L}{\lambda_1} = \frac{2Lf_1}{V}$$

$$n_2 = \frac{2L}{\lambda_2} = \frac{2Lf_1 + V}{V} = n_1 + 1 \text{ as was calculated}$$

and $n_3 = \frac{2L}{\lambda_3} = \frac{2Lf_1 - V}{V} = n_1 - 1 \text{ as we hoped.}$

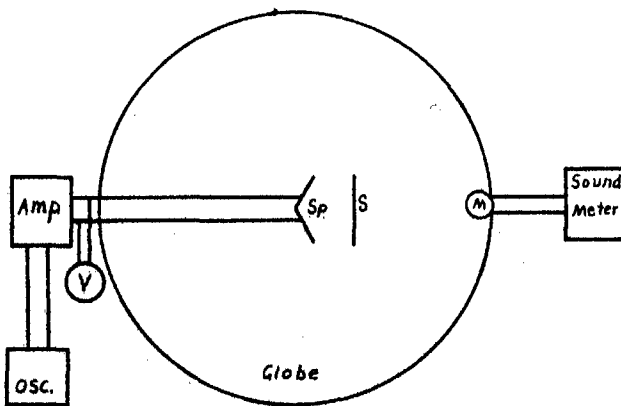


Fig. 2.

So a constant frequency variation moves the node at the lower frequency to a loop at the high frequency limit and back again. An ideal frequency wobbler would be a heterodyne, beat oscillator, for it can be shown that a constant variation in the condenser capacitance in the fixed frequency circuit will produce a constant variation in the output frequency regardless of the frequency at which the oscillator is set.

The experimental set up is shown in Figure 2. A Clough Brengle audio oscillator, variable from 50 to 16,000 cycles was used. The frequency was wobbled 460 cycles on each side of the set value by paralleling the condenser in the fixed frequency circuit of the oscillator with a small variable air condenser and rotating its rotor at 500 revolutions per minute by a small motor. Each frequency was set with the plates of the rotatable condenser half meshed so that the capacitance, and hence the frequency, was varied equally above and below the set frequency.

The oscillator was connected through an amplifier to a Wright De Coster speaker placed in a globe photometer three feet in diameter. The microphone of a General Radio Sound Level meter was placed in the window of the globe. A shield was placed between the speaker and microphone to protect the microphone from direct radiation from the speaker.

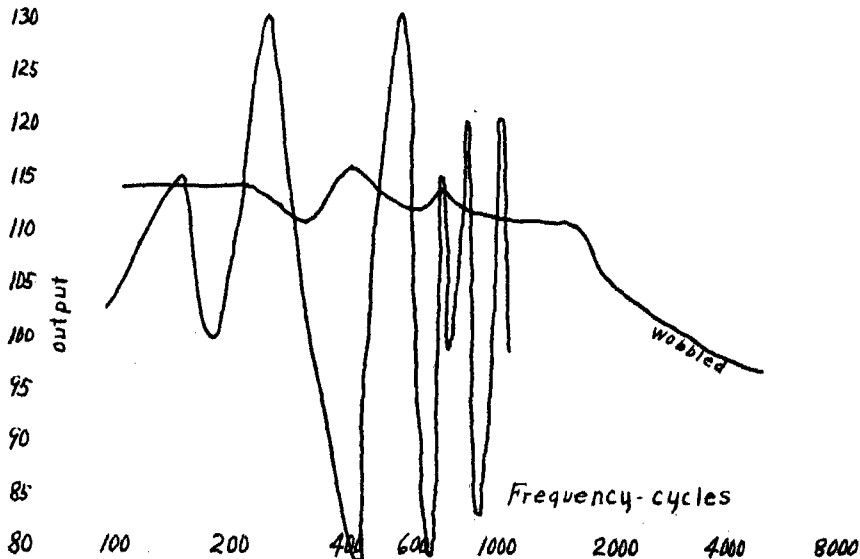


Fig. 3.

Figure 3 shows runs made with and without wobbling the frequency and is convincing proof that the sound intensity is not constant in an enclosure. The peaks occur at a fairly constant frequency increment and are, hence, due to standing waves in the globe. Due to the logarithmic scale of frequencies, the separate peaks cannot be shown beyond 1000 cycles. Hence the curve in this region is the individual readings at each even 100 or 1000 cycles.

Next the frequency was wobbled above and below the set frequency and the curve superposed on the first curve in Figure 3 to show the smoothing effect.

Figure 4 shows the frequency characteristic of the same speaker taken out of doors. The speaker was mounted on a turntable arranged to be turned on two axes at right angles to each other, and the microphone was left at a fixed position. Twenty-one frequencies were used from 50 to 8000 cycles and twenty-one different angles of the speaker. The averages of these readings were taken as proportional to the total

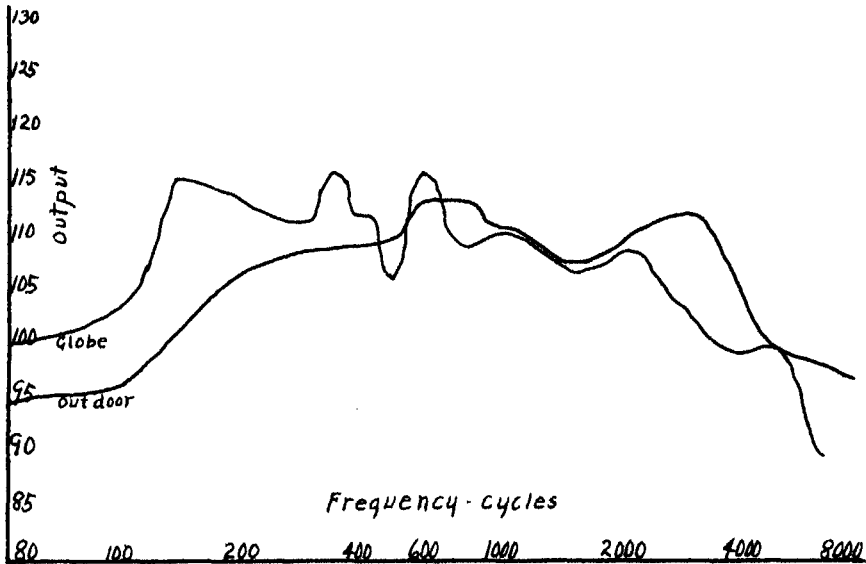


Fig. 4.

output of the speaker at any particular frequency. The readings were not reduced to an absolute level, as relative values only were needed. All output readings are the decibel readings of the sound level meter. The open air and globe-wobbled frequency curves are superposed to show the correlation between the two.

It is felt that the globe method of measuring the total output of speakers offers a considerable advantage over the rather cumbersome methods used heretofore.

This experiment was conducted in the physics laboratory of Indiana University and the electrical engineering laboratory of Ohio University under the direction of Professor R. R. Ramsey of the Indiana department of Physics.

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SECTION ON PSYCHOLOGY

Chairman: A. R. EIKENBERRY, Manchester College

Attendance at the meetings of the Section on Psychology was reported to be the largest of any meeting to date, approximately 150 persons attending some of the meetings.

At the luncheon meeting Dr. George A. Kelly, of Fort Hays Kansas State College, presented an interesting discussion on the place of the psychologist in the small school system.

Dr. F. B. Knight, of Purdue University, was chosen chairman of the section for 1939. The following were named to constitute the program committee: Fowler D. Brooks, DePauw University; Irvin T. Shultz, Butler University; and R. C. Davis, Indiana University.

ABSTRACTS

Orientations in mental deficiency. L. P. HARSHMAN, Fort Wayne State School.—The approach to the problem of feeble-mindedness is more than a study of distribution, classification, limited education, and some form of institutional care. There must be a study in the mental dynamics of the patient as applied to his individual problems of challenging the world. Stresses should be made on the reciprocal relations of importance in determining the social destinies of the defective. Only by such an approach can there grow a consciousness and a common concern relative to mental hygiene's biggest problem.

The place of the psychologist in the small school system. GEO. A. KELLY, Fort Hays Kansas State College.—Attempts to increase the annual production of the school plant have resulted in a type of organization in which administrators are removed from pupils and teachers and compelled to recognize greater responsibilities to administrative regulations and to curricula and less responsibility for the welfare of individual pupils. If the school psychologist is simply to be another specialist, we cannot justify his existence in a small school system. The place of the psychologist should be envisaged as that of a teacher without curriculum, whose major responsibility is to assist individual pupils and teachers. An outline of the typical activities of such a psychologist in a small system is presented, together with suggested plans for including his salary in the budget.

Persistence of attitudes concerning conservation issues. A. C. WILLIAMSON and H. H. REMMERS, Purdue University.—The problem of this study was two-fold: first, to measure persistence of group attitudes changed by means of defined social stimulus material, and second, to measure the variability of the groups to discover whether they become more or less homogeneous after the presentation of such material. The

results indicate that there is a significant change in attitude and in variability, and this change persists over a period of time—in this study, four months for the urban group and eight months for the rural group.

An experimental comparison of old and young coordinations in normal college adults and diagnosed pathological cases. BRYAN PAYNE, Indiana University.—With the use of the mirror-vision technique, we have been able to measure, on the one hand, the efficiency of a coordination that is genetically old in the life of the subject and, on the other hand, the efficiency of another coordination beginning relatively not so far from zero. In this study we have measured the efficiency of a day's practice in mirror-vision and of a day's practice in direct-vision for 78 diagnosed pathological cases. A day's practice consisted of ten repetitions of the task, each repetition being separated by an interval of one-half minute. Comparisons have been made with the efficiencies of normal college adults practicing under identical conditions. The following summary and conclusions seem warranted by the results of this study: (1) Pathological cases are reliably lower in direct-vision efficiency than normal college adults. (2) Pathological cases are reliably lower in mirror-vision efficiency than normal college adults. (3) The difference between direct-vision and mirror-vision efficiencies is relatively greater for pathological cases than for normal college adults. The greater deviation lies in the direction of the mirror-vision efficiency, i. e., the pathological cases are relatively lower in mirror-vision efficiency than in direct-vision efficiency. (4) We interpret these facts to mean that, while the old habit patterns are somewhat disturbed in the pathological state, they are not disturbed to the extent that the more embryonic pattern is. In terms of the eye-hand coordination, abnormality is more largely in the direction of an inability to build up the new coordination than it is to maintain the old in the face of stimulation.

A simple and direct approach to measurement of the attention value of advertising copy through eye-movement photography. JAMES S. KARSLAKE and JOSEPH TIFFIN, Purdue University.—A photographic technique placing advertising copy at reading distance and approximating normal reading conditions has been developed to meet very nicely precisely those factors which are peculiar to the determination of consumer interest in advertising. A method of direct photography, recording eye-movements by reflection from a half-silvered mirror together with a picture of the page or pages by transmission through the mirror, has been found to yield to a sufficiently accurate approximation of fixation areas just what material, if any, is of consumer interest. Six people without previous experience were able to judge ten looks at several pages of a well-known periodical, correctly identifying 58 of their combined total of 60 placements.

The distribution of muscular action potentials during maze learning. ROBERT S. DANIEL, Indiana University.—The problem of the amount of muscular tension concomitant with the acquisition of a motor skill in an assigned task is the basis of this research. Results of the study indicate a differential level of tension for the four body positions studied,

which is maintained throughout the learning. However, the most significant conclusions are derived from the curves of the progress of tensions as the task is mastered. Early tensions were high as the subject approached the job. Tension levels fall in every member towards the middle of the practice series, then rise again as the last trial approaches. Statistically, the early decline in tensions (progressive relaxation) is associated with the attempt of the subject to eliminate errors or to achieve accuracy. The later rise in tensions is in the same way associated with the attempt of the subject to increase his speed. This interpretation of the results is made in connection with a peripheral-motor theory of learning.

An experiment in shifting attitudes. HARRY MASON, Purdue University.—A group of 57 seniors in the West Lafayette High School were given attitude scales concerning the attitude object: That a half-time schedule of opportunities to learn while on jobs in businesses be substituted for the traditional system of high school administration. A test of information on subjects relating to the vocational adjustments of youth was also presented. Propaganda intended to shift attitudes toward favor for the proposal was introduced, and the same scales and tests repeated. Interesting relationships between attitudes, intelligence, and information were evident upon analysis of the data by statistical means. By use of two techniques of measurement of attitude, some theoretical considerations of measurement in this field were brought to light.

A practical test for punch press operators. NATHAN B. GEWIRTZ, Purdue University.—Following the principle that a psychological aptitude test is usually more valid when it closely approximates the job, a test for punch press operators has been constructed, the press of the same general design as that used in industry. The operator is asked to put 50 plates through the press four times, making a total of 200 pieces. Two scores are obtained—a time score and an error score. Preliminary norms, as well as a comparison between unselected persons and experienced punch press operators, are presented. Correlations obtained from this preliminary data between efficiency ratings and scores on the test are discussed.

Industrial psychology. JOSEPH TIFFIN, Purdue University.—The test, used to supplement present methods of employment, attempt to give a picture of the actual efficiency of an employee before he is hired. In each case the test is "tested" on present operators before it is recommended to the employment manager. "Testing" the test on present operators involves giving the test to a fairly large number of present employees and determining whether those who test high tend in general to be more efficient than those who test low. In this way it may be determined definitely whether the test will pick efficient operators. Obviously, in using present employees to test the test, the results would have no bearing whatsoever upon the present status of those employees of the company. An experimental testing program of the type described has been under way for some time in two plants. Results show

clearly that manipulative operators can be selected with considerable precision by means of such tests as finger dexterity, hand precision, and keenness of vision.

The person as a laboratory subject, as a statistical case, and as a clinical client. GEO. A. KELLY, Fort Hays Kansas State College.—The definition of the science of psychology eventually will be written by those who are not psychologists. It is difficult for anyone except a confirmed psychologist to see the laboratory subjects of the academic psychologists as the same human beings who inhabit the land. It is somewhat easier for an administrator, an economist, or a social worker to recognize the statistician's case as a workable entity. Great numbers of intelligent and interested laymen who have been newly awakened to so-called human values are thinking in terms of clinical clients and what the psychologist does for them. This forcing of the psychologist's hand may draw him into scientific inaccuracies or may cast for him a new and more vital role. Illustrations of the problems which psychologists will be expected to solve are offered.

Responses of Psychotic Patients to the Thurstone Personality Schedule before and after Metrazol Treatment

WILLIS H. McCANN, Indiana University

This research¹ took place at the Missouri State Hospital for the Insane at Nevada, Missouri, during the summer of 1938. The purpose of the investigation was to see how psychotic patients would respond to the Thurstone personality schedule before and after receiving the metrazol shock treatment.

Because of the short period of time available, the investigation was limited to 26 patients, 12 males and 14 females, ranging from 17 to 52 years of age. According to the hospital classifications, 21 were schizophrenes (12 hebephrenics, 4 paranoids, 3 simplex, and 2 catatonic); 4 were manic-depressives (2 depressed and 2 maniacal); and one was a case of involutional melancholia. All 26 had been admitted to the hospital since 1930, and half of them had been admitted in 1938.

Before beginning the metrazol treatments 11 of these patients gave "yes", "no", or "doubtful" responses to the questionnaire. The remaining 15 patients were either unwilling or unable to cooperate. Metrazol was given on an average of twice a week for an indefinite period, depending upon the progress of the patient. The initial amount of 2.5 cc. for females and 5 cc. for males was increased from time to time so that each successive injection would produce the so-called "shock" or "convulsion."

The answers to the questionnaire were scored according to the Thurstone scoring system and also according to the method devised by Dr. E. S. Conklin of Indiana University.² With Dr. Conklin's scoring device an abnormal, a psychotic, and a schizoid score were obtained for each personality schedule.

There were only five patients who cooperated by giving "yes", "no", or "doubtful" answers both before and after receiving metrazol. Their Thurstone scores ranged from 39 to 117 with an average score of 81.6 before metrazol and from 42 to 153 with an average score of 82.4 after metrazol. Their abnormal scores (which, for 100 college students, averaged 7.45) ranged from 11 to 26 with an average score of 22.4 before metrazol and from 9 to 38 with an average score of 19.2 after metrazol. Their psychotic scores (which, for 100 college students, averaged 5.18) ranged from 6 to 13 with an average score of 8.6 before metrazol and from 1 to 15 with an average score of 7.4 after metrazol. Their schizoid scores (which, for 100 college students, averaged 3.93) ranged from 3 to 11 with an average score of 6.6 before metrazol and from 1 to 17 with an average score of 7.8 after metrazol. The number

¹ This research was suggested by Dr. E. S. Conklin, Indiana University.

² Conklin, E. S., 1937. Three diagnostic scorings for the Thurstone personality schedule. Indiana Univ. Publ., Sci. Ser. 6.

of metrazol treatments ranged from 6 to 13 with an average of 10.4. Of these five patients, one, a hebephrene, showed definite improvement; two, a hebephrene and a simple type, remained unchanged; and two, a hebephrene and a paranoid type, became definitely worse. These observations were corroborated by the hospital staff, with one exception, a 22 year old girl classified as schizophrenia, simple type, who showed some improvement although her scores indicated no change in her condition.

Six patients gave "yes", "no", or "doubtful" answers before receiving metrazol but were unwilling or unable to cooperate after receiving the treatment. Their Thurstone scores ranged from 36 to 131 with an average score of 88; their abnormal scores ranged from 9 to 38 with an average score of 23.8; their psychotic scores ranged from 3 to 13 with an average score of 9.5; and their schizoid scores ranged from 3 to 13 with an average score of 10. The number of metrazol treatments ranged from 10 to 19 with an average of 13.1. All six (two hebephrenes, one paranoid type, one simple type, one depressed, and one maniacal) became worse during the series of treatments. One of them, a 34-year-old male classified as schizophrenia, paranoid type, had been admitted to the hospital in 1934 and since then had received a series of 53 insulin treatments. He also had received a series of 10 metrazol treatments during the spring of 1938. During the present metrazol series his condition became much worse. These observations were all corroborated by the hospital staff.

Twelve patients were unwilling or unable to cooperate before receiving metrazol but gave "yes", "no", or "doubtful" responses to the questionnaire after the treatment. Their Thurstone scores, which it must be remembered were obtained only after metrazol treatments, ranged from 13 to 106 with an average of 50.4. Their abnormal scores ranged from 5 to 26 with an average of 12.0. Their psychotic scores ranged from 1 to 13 with an average of 7.0, and their schizoid scores ranged from 2 to 10 with an average of 5.8. The number of metrazol treatments ranged from 5 to 21 with an average of 11.5. All twelve of these patients (five hebephrenes, two paranoids, two catatonics, one depressed, one maniacal, and one involutional melancholia) showed improvement, and six of them were paroled from the hospital.

Three patients were unwilling or unable to cooperate both before and after receiving metrazol. One of them was a 24-year-old male, classified as schizophrenia, simple type. He was admitted to the hospital in 1934 and since that time had received a series of 59 insulin treatments. In the spring of 1938 he received a series of 24 metrazol treatments, and during the present metrazol series he received 7 treatments. His condition was apparently becoming much worse. Another was a 25-year-old female, classified as schizophrenia, hebephrenic type. She was admitted to the hospital in 1930 and had not received any insulin or metrazol prior to the present series of treatments. After receiving 11 metrazol treatments her condition was also becoming much worse. The third patient was a 25-year-old male classified as schizophrenia, hebephrenic type. He was admitted to the hospital in 1937 and later paroled after receiving a series of 25 insulin treatments. This

patient was returned to the hospital last July and immediately started the metrazol series. No change was apparent in his condition after seven treatments.

These results may be summarized as follows: Of 26 patients, five gave "yes," "no," or "doubtful" responses to the questionnaire both before and after receiving metrazol. Only one of these five showed definite improvement, two remained approximately unchanged, and two became definitely worse. Six patients gave "yes," "no," or "doubtful" answers before receiving metrazol but were unwilling or unable to cooperate after the treatments. Twelve were unwilling or unable to cooperate before receiving metrazol but did cooperate after the series of treatments. Three were unwilling or unable to cooperate both before and after the series of treatments. Judged by their reactions to the questionnaire, 13 of the 26 showed improvement, five remained approximately unchanged, and eight became definitely worse. These data are, of course, suggestive rather than conclusive. In general, they indicate that either the metrazol produced no consistent pattern of change in the personalities of the 26 patients or our method of measuring personality changes was inadequate.

Measuring Affective Experience

H. E. GEIGER, Purdue University

The Problem

The experiment which I am reporting was designed to investigate a problem directed toward further simplification and improvement of attitude measurement techniques. Since the study is still under way, it will be possible to give in this paper only a brief resume of a preliminary study and a description of the progress and the objectives of the major study. The nucleus of this investigation has grown out of a rather critical analysis of the several methods which have been used in the measurement of attitudes.

It may be recalled that most of the instruments used in measuring attitudes make use of statements about some attitude object. In some of the scales, such as those begun by Thurstone¹ and the variations developed by Remmers,² subjects are allowed to express their attitudes by indicating those statements with which they agree. In others, such as those proposed by Likert,³ subjects are allowed to indicate an amount or degree of agreement with statements.

When these statements are carefully analyzed, it may be observed that usually only one or two words in each statement are important in determining its favorableness or unfavorableness. A few words, such as "interesting" and "uninteresting" or "desirable" and "undesirable," are the key words which allow subjects to express favorable and unfavorable responses. Some statements have contained qualifying words expressing how desirable or how interesting, as for example "slightly interesting" or "very desirable."

This paper is primarily concerned with the functioning of these key words. They may be classified into two types, those indicating favorableness or unfavorableness which we shall call "directional words" and those indicating an amount of favorableness or unfavorableness which we shall call "intensity words."

If the element in the language which indicates an individual's attitude is contained in these directional words and intensity words, it would seem to be possible to combine them into phrases, obtain scale values for these phrases, and use them in much the same way that statements have previously been used in attitude measurement. For example, the directional word "inspiring" which points toward or indicates a favorable reaction, plus the intensity word "greatly" which tells how inspir-

¹ Thurstone, L. L., and Chave, E. J., 1929. Measurement of attitude toward the church. Univ. Chicago Press, p. 2.

² Remmers, H. H., 1934. Studies in attitudes. *Studies in Higher Educ.*, 26; *Bull. Purdue Univ.* 35.

³ Likert, Rensis, 1932-33. A technique for the measurement of attitudes. *Archiv. Psychol.* 22.

ing, together constitute the phrase "greatly inspiring" which, it would seem, could be used to express how one felt about a speech, a teacher, or a book. If scale values could be obtained for all such phrases expressing the direction and the intensity of one's reactions, it should be possible to measure reaction toward any situation by simply selecting appropriate phrases from the list.

In terms of attitudes if one wished to measure, let us say, attitude toward a teacher, he would need to select from the list of scaled phrases a number of phrases which would allow one to express a reaction toward a teacher. That group of phrases might then be thought of as a scaled measuring instrument since values for each of the phrases would be known. In a similar manner other groups of phrases might be selected for measuring other attitudes. Such a technique would greatly reduce the labor involved in the construction of measuring instruments and, at the same time, increase the possibility of measurement to an infinite number of objects or situations.

Preliminary Experiment

At the time this problem was being formulated it became possible, in connection with another study, to test out, in a measure, the success which might be expected in scaling phrases apart from other sentence structure. Although the phrases in this preliminary study required a comparison of two objects or situations, the study seemed to support the hypothesis that single phrases may be scaled quite successfully.

In this preliminary experiment, 14 phrases expressing degrees of comparison were used. They were designed to represent two continuums as follows: (1) Very much inferior, much inferior, slightly inferior, equally as good, slightly superior, much superior, very much superior; (2) very much less often, much less often, slightly less often, equally as often, slightly more often, much more often, very much more often.

Scale values were obtained separately for each of these expressions by the psychophysical method of equally often observed differences. The sheet which you have indicates graphically the scale values for the two continuums. The tables show the scale and Q-values on a 7-point continuum and the probable Q-values on an 11-point continuum. It will be noted that the expressions received values on a 7-point continuum which closely correspond to the seven integers spaced at equal intervals along an arbitrary continuum. Q-values compare very favorably with Q-values obtained on items which have been used in attitude scales. From the results obtained in this preliminary experiment the scaling of single phrases seemed plausible, and the major experiment was set up.

The first step in the major experiment was the selection of a sufficiently extensive list of suitable phrases. A preliminary investigation of words and their meanings seemed to indicate that such phrases might well be limited to those expressing an affective experience. They are, at least from the standpoint of logic, the fundamental expressions of attitude; and, inasmuch as it may be observed that many statements used in attitude scales simply describe the attitude object,

it would seem possible that such statements might be less indicative of a true reaction than statements directly expressing affective experience. Attitude can only be secondarily inferred from a descriptive statement. For example, if a child said that a teacher was strict, we should probably infer that the child disliked the teacher, but quite the contrary may have been true. On the other hand, if the child said that he liked or disliked the teacher's rules, there could be no mistake. Of course, this is a hypothesis, and its empirical validation should be considered as an auxiliary part of this experiment.

With this delimitation to words clearly expressing an affective experience, Roget's *Thesaurus of English Words and Phrases* was carefully searched for all suitable words, and the three following lists were compiled.

1. Directional words expressing a favorable response.
2. Directional words expressing an unfavorable response.
3. A list of intensity words which could be used to express an amount or degree of favorableness or unfavorableness.

Words having equivocal meaning were eliminated. Even though such words as "thrill" and "provoke" express affective experience, they are not useful as directional words because they sometimes have favorable and sometimes unfavorable connotations.

After the undesirable words were eliminated, there remained 108 positive directional words, such as acceptable and admirable, 146 negative directional words, such as disagreeable and displeasing, and eight intensity words, such as slightly and decidedly. It is interesting to note that there are many more ways of expressing unfavorableness than there are of expressing favorableness.

The directional words were set up in tabular form in order to study their applicableness to many different types of objects and situations, and it was discovered that a rather small number of these words could be readily applied to most situations. Although it is planned eventually, if necessary, to obtain ratings on all of the directional words, each in combination with several different intensity words, for the present experiment only ten were taken from each of the favorable and unfavorable lists. It is believed that the number of intensity words it will be necessary to use may be reduced to as few as three or four when it is learned how advantageously they space themselves along the continuum.

The experiment has been carried only to the point of scaling. However, an exhaustive study of reliabilities and of various functions of measuring instruments made up of phrases selected from the scaled list has been outlined. If it is found that the scaled phrases function satisfactorily as measuring instruments, when the complete list is scaled it will be possible to measure any affective experience by simply using the appropriate phrases.

This experiment should be particularly interesting to those who have been interested in the science of semantics.

A Technique for Measuring Consumer Attitude Toward Any Advertisement

RUTH H. KARSLAKE, Purdue University

Most of the existing methods for evaluating advertising are unsatisfactory for various reasons. So-called laboratory techniques, which can most satisfactorily isolate the necessary variables, are often unsuitable because they create artificial situations which are not strictly comparable to the ones in which advertising is used. Those field surveys or measures of consumer response to advertising which give satisfactory results are impractical from the point of view of the costs involved. Also, the question of reliability of these methods has not been satisfactorily dealt with in many cases. It appears that there is needed a simple, economical instrument which may be used as a reliable index of the value of any advertisement as measured in terms of consumer reaction to it.

According to Link (3), "Among all methods of measuring the relative effectiveness of advertising, that of submitting ads to the judgment of selected groups of people would be the most valuable if its reliability could be determined."

In constructing such an instrument, it was decided to employ a technique suggested by Likert (2). For the measurement of attitudes he has evolved a method which he found to give as high reliabilities as were obtained by the Thurstone attitude scales (5). Likert's method, besides eliminating much of the labor involved in constructing a Thurstone scale, does not depend upon the principle of determining scale values for statements by means of a judging group. Recent studies at Purdue (1) have demonstrated that this method can be satisfactorily applied to the type of statements used in the generalized attitude scales developed by Remmers (4).

Accordingly, it became the purpose of the present study to construct and evaluate an instrument, following Likert's technique, for the measurement of consumer attitude toward any advertisement.

Likert's method involves a battery of statements expressing various attitudes toward an attitude object. Each statement is a scale in itself by virtue of the several alternatives by which the subject responds to it. The present study employed the following seven alternatives of response to each statement: strongly agree, agree, mildly agree, indifferent, mildly disagree, disagree, strongly disagree. Following Likert, the investigator found a satisfactory method of scoring to be the assigning of numerical values from 7 to 1 to each of these response alternatives. In statements expressing a negative attitude, this weighting was reversed. An individual's score could then be computed by averaging or summing the numerical value of the response to each statement, a comparatively high score expressing a more favorable attitude than one which is comparatively low.

The first step in the construction of the instrument was the collection of statements which would be indicative of consumer attitude toward any advertisement. In order to make these as representative as possible, the reactions of 25 subjects to 30 advertisements were collected. These were full-page advertisements, both colored and uncolored, which seemed representative of good and poor advertising for certain products for which the group might be expected to be potential consumers.

From these reactions, 354 statements which seemed most suitable were assembled. The second step, was the judging of the statements by six members of the psychology staff of Purdue University. They rated the statements as good, fair, and poor, in accordance with a criteria set up for them as to the purpose of the instrument.

The third step was the selection for a preliminary battery of the 50 statements indicated by the judges' ratings to be the best. Each statement chosen was rated good by at least five of the six judges. Twenty-five positive and 25 negative statements were chosen by the investigator from the group which seemed best according to the judgments expressed.

The fourth step involved the administration of the preliminary instrument to 50 subjects, 25 men and 25 women, associated with Purdue University. Each subject rated each of six advertisements on the basis of these 50 statements. Six full-page advertisements, five colored and one uncolored, were used. Three displayed products; two, services; and one, good-will.

From scores obtained by summing the numerical values of the subject's response to each statement, the instrument was evaluated as to reliability and validity. Reliabilities of the instrument for the first four advertisements were found by the split-half method of correlation. These ranged from $.96 \pm .01$ to $.98 \pm .003$. In view of these very high reliabilities and the fact that the instrument seemed too long to be practical, the Spearman Brown formula was applied to determine what the reliability would become if the test were shortened to 40% of its present length. R's were predicted of $.90 \pm .02$ to $.95 \pm .01$, indicating satisfactory reliability if the instrument followed the prediction.

By computing the percentages of subjects whose total score on the battery for a given advertisement was at or above the indifference point, a rank order rating of the advertisements was obtained for the scale data. A validating criterion, based upon reactions of another group to these same advertisements, also enabled a rank order of preference to be established. For the two techniques the ranks were identical except for the reversed order ranking of the advertisements standing 1 and 2 and 4 and 5. A rank difference correlation was found to yield a P of $.93 \pm .01$.

The number of statements was reduced to 20 for the final instrument by selecting those which seemed to be the most discriminating of a favorable or an unfavorable attitude, on the basis of the number of responses of indifferent which each received for all of the six advertisements. Ten positive and ten negative statements were selected.

The data from the preliminary administration were rescored on the basis of the 20 statements selected for the final scale. The split-half reliabilities ranged from $.89 \pm .02$ to $.94 \pm .01$. Since these all fell within

the allowable error range of the reliabilities for 20 statements predicted by the formula, it seems that the Spearman-Brown formula did predict accurately for this data.

A second group of 25 men and 25 women students of Purdue University were then asked to rate the same advertisements on the basis of the final instrument of 20 statements. Split-half reliabilities were found to range from $.78 \pm .04$ to $.94 \pm .01$.

In order to have a larger group upon which to base the reliabilities, it was considered desirable to combine the data obtained from the first group on the basis of 20 statements with that of the second group. That the groups were fairly comparable was shown by the similarity of the sigmas of the distributions of their scores. Split-half reliabilities for the entire group of 100 were found to range from $.84 \pm .02$ to $.92 \pm .01$. Ranking by percentages gave the same order of preference as was obtained from the 50 subjects on 50 statements. Therefore, the rank difference correlation with the criterion was again found to be $.94 \pm .01$.

It would seem that within limitations imposed by method the instrument appears to give satisfactory results. Although the numbers of subjects used were too small to be conclusive, it appears that the instrument is measuring, by the crude index employed, a function rather closely related to that of the validating criterion. So far as the conditions of this investigation permit, the battery appears to be reasonably satisfactory. It should be useful, especially in view of its simplicity and economy, as a means of determining the relative merits of various types of advertising.

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The Construction and Evaluation of a Scale to Measure Attitudes of Stutterers Toward Any Social Situation

ELNA S. HUFFMAN, Purdue University

Introduction

During the past decade the psychology of stuttering has become a matter of growing interest and concern. Attitudes of stutterers have been determined by case histories, biographies, questionnaires, and rating scales. It is desirable to replace these crude methods with more rigorous and exact methods of measurement. The primary purpose of this study was to construct an attitude scale to measure attitudes toward any social situation.

The Thurstone technique of attitude scaling, based on the assumption that equally often observed differences are equal, was used throughout the study.¹ By applying the Remmers' modifications,² a master scale was constructed which can measure attitude toward several social situations at the same time. The acceptance or rejection of statements of opinion was used as the index to affect measurement.

Scale I construction:—A number of statements of opinion, general in nature and applicable to both stutterers and non-stutterers, was collected and submitted to five members of the psychology staff at Purdue for rating on a 3-point scale: (1) excellent, (2) fair, (3) worthless. All statements checked worthless by two or more judges were eliminated. Remaining statements were mimeographed and administered to 223 college students for allocation on an 11-point scale, according to the degree of favorableness³ or unfavorableness to any social situation indicated by the statement. Frequency distributions were then set up for each of the statements, and their respective medians and Q-values computed. The median value of a distribution for a statement became the scale-value for that particular statement. All statements having a Q-value of over three were discarded as being ambiguous. In assembling the scale, statements were selected so as to cover the whole range of favorableness and so as to be approximately equi-distant. Alternate forms were constructed by using as parallel statements those having approximately the same median and Q-values. The reliabilities of the scale-values were:

Form A, Standard Error of the Scale Value $.108 \pm .07$ scale units

Form B, Standard Error of the Scale Value $.109 \pm .07$ scale units

Scale I evaluation.—To determine reliability of the instrument, it was given to 200 college students. The correlation of Form A with Form B was $.79 \pm .02$.

Validity was found by administering the scale to 2 groups judged to differ in attitude toward a social situation. Judges were the Assistant

¹ Thurstone, L. L., and Chave, E. J., 1929. *The measurement of attitude*. Univ. Chicago Press.

² Remmers, H. H., and Silance, Ella B., 1934. A generalized attitude scale technique. *Journ. Social Psychol.* 5:298-312.

³ Seashore, R. H., and Hevner, Kate, 1932. A time-saving device for construction of attitude scales. *Journ. Social Psychol.* 5:367-373.

Dean of Women, the Director of the Women's Residence Halls, and two sponsors in the Men's Residence Halls. There were 75 subjects in each group. The reliability of the difference between the means of the two groups yielded 97 chances in 100 of a true difference; using difference as determined by percentages, the chances were 100 in 100 of a significant difference.

Scale II construction.—Scale II, constructed specifically for stutterers, contained some items relating directly or indirectly to stuttering. Therefore, the statements were criticized by members of the Purdue Speech Clinic Staff and after revision sent to various speech clinics for stutterers to allocate on the 11-point scale of favorableness. Because of the extreme difficulty in obtaining subjects, there were only 76 raters. These statements were submitted to the same statistical procedure as Scale I. It is significant that, when the objective measure of ambiguity was applied, the majority of statements relating to stuttering proved to be ambiguous. The reliability of the scale-values were:

Form A, Standard Error of the Scale Value $.213 \pm .15$ scale units

Form B, Standard Error of the Scale Value $.211 \pm .14$ scale units

Reliability and Alternatives of Response.—The Problem: Does increasing $2\frac{1}{2}$ times the alternatives for response to each statement of opinion increase the reliability of an attitude scale as predicted by the Spearman-Brown prophecy formula?

Two scales were constructed, identical in every respect except the possibilities of response. Each scale had equivalent forms. In the first scale, Forms A and B, the directions were to either agree or disagree with each statement of opinion. The other scale, Forms X and Y, offered the subject a choice of 7 responses to each statement: (1) Strongly agree; (2) Agree; (3) Mildly agree; (4) Indifferent; (5) Mildly disagree; (6) Disagree; (7) Strongly disagree. All four forms were given to 50 students.

The reliability of the test having but two alternatives of response was found to have approximately the same reliability as the scale having seven alternatives for response.

Correlation of Form A with Form B = $.732 \pm .04$

Correlation of Form X with Form Y = $.734 \pm .04$

Therefore, the tentative conclusion is that the reliability of an attitude scale is not increased by the addition of alternatives for response.

Conclusions

1. Scale I, the general scale applicable to both stutterers and non-stutterers, would be efficient as a means of measuring group attitudes toward any number of social situations.

2. Scale II, constructed specifically for stutterers, does not differ appreciably from Scale I, since most of the statements relating to stuttering had to be discarded.

3. Increasing alternatives for response to statements in an attitude scale does not increase the reliability of the scale as predicted by the Spearman-Brown prophecy formula. Conclusions, based on a population of less than 100, must be considered tentative. It is for further research to determine the accuracy of the indications of this experiment.

A Study of Sex Differences in Food Likes and Dislikes¹

LYLE TUSSING, Purdue University

Very little information is available concerning the food preferences of men and women. The kind of satisfaction people get out of eating shows a marked difference among individuals. Most people have favorite dishes and pet abominations among foods. Doubtless, violent dislikes for generally accepted foods frequently originate in unpleasant experiences connected with them. Such an experience might be indigestion. The reasons for extreme likes would be less easy to trace. They may have a similar origin in forgotten pleasures somehow connected with things that now arouse them.

Although there is a wide variation of preferences, it is recognized that in the last analysis all tastes in food can be reduced to four or at the most six fundamental kinds—sweet, sour, bitter, salt, alkaline, and metallic, separately and in combinations. Any blend of these with pressure, pain, warmth, cold, and various odors, make up all of the varieties of taste we experience in foods.

Not only are there individual likes and dislikes for foods, but also there is a belief in the existence of a definite sex difference in these likes and dislikes. Dunlap² makes the following statement:

A recent investigation on the likes and dislikes of men and women has brought out the indication that woman is relatively stronger in her dislikes, man in his likings. There are matters of secondary desires and aversions, of course, and it is not certain yet that it is generally true. Yet, certain common-place observations, especially in regard to foods, seem to bear out this conclusion. The results of wider experimental work on this point will be important.

Procedure

In order to make a trustworthy investigation of the variations due to sex alone, it is essential to secure subjects for the investigation of both sexes who are near the same age, who have the same social status, and who have been subjected to like training and social surroundings. The complete fulfillment of these conditions, even in the most democratic community, is impossible. Probably the nearest approach among adults to the ideal requirement is afforded by the undergraduate students of a co-educational institution.

The individuals who furnished the basis for the present study were students of Beloit College, Beloit, Wisconsin. They were from all four classes, freshman, sophomore, junior, and senior. Their ages ranged from 17 to 25 years. Questionnaires were given to these young men and women with the following instructions:

Below are lists of foods which we would like to have you check (✓) according to whether you like them, are indifferent to them, dislike them, or have never tasted them.
p. 228.

Four columns were provided for checking and headed with the above titles.

¹ The data reported here were gathered at Beloit College. F. Dunlap and B. Woodruff kindly assisted in the collection and tabulation of the questionnaire reports.

² Dunlap, Knight. Social psychology. Williams and Wilkins. p. 42.

Only the columns of "like" and "dislike" were tabulated, but it was considered necessary to include the other two columns in the questionnaire form so that the subjects would not be inclined to check as "dislike" all foods which were not actively liked and as "like" all foods not actively disliked. In other words, we were interested to know whether their reaction was one of approaching or avoiding. This procedure also explains why the percentages of the "like" and "dislike" columns do not total 100% in each case. A certain percentage of items were eliminated from the record sheet because they were checked as either "never tasted" or "indifferent." Questionnaires were returned from 184 males and 214 females.

The list of 289 items of food was assembled by consulting numerous cook books and manuals on home economics. Not all of the possible foods were listed nor all of the ways of preparing them. The list, however, was considered as presenting a fairly representative selection of foods and could be used effectively in the time available.

Results

The percentage of men and women liking and disliking was figured by dividing the number checking the liked (or disliked) column by the total number of that sex and computing it to the nearest whole number. However, fractions less than 1 (0 to 1) were considered 1%. To a large extent edibles which are liked by a large majority of men are also liked by a large majority of women. Some items which show a wide variation between the sexes include raisin and mincemeat pie, milk, poached eggs, rice, coconut cake, tuna fish, grouse, quail, and figs. There is also a similarity between the sexes regarding their dislikes. Here, such foods as raisin pie, avacados, milk, rice pudding, and creamed cabbage show the greatest differences.

When we consider the foodstuffs which are liked, we find that 172 of the 289 items are liked by a greater percentage of men than women, 23 are liked to the same extent, and 94 items are liked more by the women than by the men. Or from the percentage standpoint, 59% of all the foods liked are liked to a greater extent by men than by women, 8% show the same liking by the sexes, and 33% show a greater liking by the women. When we examine the food disliked, we find that the women indicate a greater dislike than the men for 174 items (60%); in 80 items (28%) the difference is in favor of the men, and in 35 items (12%) they are the same. From this it appears that the ratio is about 2 to 1 in both the likes and dislikes, a greater percentage of women disliking items and a greater percentage of men liking them.

There is a statistically significant difference¹ in 49 cases. Of the 172 items liked by men we find that 31 items show a significant difference. Of the 94 foods liked more by the women than by the men, 4 were significant. In the dislikes there are three cases having a significant difference in favor of the men and 11 in favor of the women.

From this investigation of food preferences it appears that women are relatively stronger in their dislikes; men, in their likes.

¹ Garrett, H. E., 1927. *Statistics in psychology and education*. Longmans, Green. p. 223.

SECTION ON ZOOLOGY

Chairman: HENRY G. NESTER, Butler University

The attendance at the section on zoology maintained an average of between 50 and 60 throughout the session. The following named demonstrations were given: the use of the Argus camera in the biological laboratory, Caudata of Vigo County, juvenile forms of *Acanthocephala*, and the spotted turtle, *Clemmys guttata*. Other papers were also supplemented by demonstration material.

C. P. Hickman, of De Pauw University, was elected chairman of the section for 1939.

ABSTRACTS

The centennial of the cell theory of Schleiden and Schwann, 1838-1938. HENRY G. NESTER, Butler University.—Biographical sketches of the two authors of the cell theory are given. Some of Schwann's scientific work is mentioned. Schwann's "Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants" and Schleiden's "Contributions to Phytogenesis" are reviewed. Bibliographies of the two men are included.

Insects of Indiana for 1938. J. J. DAVIS, Purdue University.—Each year finds us confronted with a changed insect population. During the past year many insect problems have confronted the citizens of Indiana. Army worms destroyed field crops early in the season; grasshoppers were abundant, but, because of the heavy rainfall and resulting luxuriant vegetation, they did not cause severe losses; the Hessian fly built up to threatening numbers, especially in the northern half of the state; and for the first time since its introduction into Indiana, the European corn borer caused commercial losses in the eastern part of the state. Garden pests, especially the Mexican bean beetle and leafhoppers, caused severe losses in many parts of Indiana. Annoying pests, including mosquitoes and fleas were unusually abundant. Scale insects, including the European elm scale, the cottony maple scale, and the San Jose scale, were on the increase. Fruits were likewise subject to heavy toll by the Oriental fruit worm and codling moth. These and many others are discussed.

Further observations on conditions under which fresh-water medusa, *Craspedacusta*, occurs. MURVEL R. GARNER, Earlham College.—The medusa has now been found to occur in seven of the last eight years in this same body of water, indicating that conditions appear to be satisfactory for its permanent residence there. Furthermore, the medusae have been found in two other artificial bodies of water within a few miles of Richmond, one of which has contained them at least three or four summers. As a means of determining the conditions under which these animals live, physical and chemical data concerning the water and a description of the bodies of water are given. It is hoped that other investigators will contribute similar data as a means of determining the conditions of occurrence of this form.

Radiation of *Drosophila* with low-intensity ultra-violet light for one complete generation. III. Effect on crossing-over in the second chromo-

some of the male. S. A. RIFENBURGH and MARTHA WALKER, Purdue University.—Abstract withheld until study is complete.

The Golgi material in the parathyroid gland cells of vitamin-D-deficient albino rats. HENRY G. NESTER, Butler University.—Ten albino rats, the mothers of which had been on a diet deficient in vitamin D during lactation, were placed on Steenback ricket-producing diet 2965 when 29 days old and kept on it for 31 days. They were then killed and the parathyroids preserved in a modification of the Nassanov Kolatchev method, and the tibias were tested by the McCollum line test. The same procedure was followed with animals kept on a normal diet. Preliminary observations show that the Golgi apparatus of the parathyroid gland cells of animals receiving a normal diet is larger and more complex than that in the animals deficient in vitamin D.

A preliminary report on the life history of a species of *Amphimerus* (Trematoda: Opisthorchiidae) from the snapping turtle (*Chelydra serpentina*). RAYMOND M. CABLE, Purdue University.—Among a large number of parasites found in a snapping turtle from Madison County, Kentucky, were 42 specimens of *Amphimerus*, which were taken from the gall bladder and bile ducts. Twenty-two of these were teased apart and placed in aerated water until the eggs contained active miracidia, but none of the eggs were observed to hatch. Each of 10 small specimens of *Goniobasis semicarinata* was isolated with a small portion of worm material containing embryonated eggs, and at intervals the snails were cracked and examined for parasites. One died, four became infected, and five gave negative results. The last infected snail, examined 90 days after infection, contained 24 cercariae that were capable of swimming. The other infected specimens did not contain mature cercariae but yielded large numbers of rediae of the type characterizing the *Pleurolophocera* group. Both mother and daughter rediae were observed, apparently for the first time in this group. Larval stages of none of the other seven trematodes known to parasitize this snail were found in the experimental material. Since the natural incidence of infection with all species is low in this mollusk, and the specimens used were very small, it seems quite probable that the infection resulted from the ingestion of the eggs of the parasite. The second intermediate host has not been discovered.

Star-recessive and Trim, spontaneous mutations on the second chromosome of *Drosophila melanogaster*. EDWARD B. LEWIS, JR., Minneapolis, Minn.—Star-recessive (symbol S^*), a recessive allelomorph of the dominant gene for Star-eye (S , 2-1.3), produces a rough eye in the homozygous state. Its phenotypic expression, however, is more variable than that of $S/+$, while the combination S/S^* results in a new phenotype. A series of experiments show S^* to be located on the second chromosome and prove its allelomorphism with Star. Trim (symbol trm) is a recessive mutation resulting in scalloped wing margins. An interesting feature is the complete infertility of the homozygous trm female—a condition uncommon although not unique among autosomal recessives. The final localization of trm is made by a special type of crossing-over experiment known as a balanced viability test.

Notes on the Hypogaic Ant, *Proceratium silaceum* Roger

CLARENCE HAMILTON KENNEDY, Ohio State University, and MARY TALBOT,
Lindenwood College, St. Charles, Missouri

To complete the technical description of the species we give first a description of the male, which to date has remained undescribed.

Description of the Male

The following description deals largely with characters which differ from parallel characters in the male of *Proceratium croceum* Emery described by M. R. Smith (1930). The type male is from a nest of 5 males and 9 workers collected by C. A. Dennis on the south sand spit of Pelee Island, Ont., August 25, 1936 (Kennedy coll., No. 2361). The workers are of the lighter of the two forms of *silaceum* discussed elsewhere in this article. We have no males of the darker form. Neither have we been able to study males of *croceum*.

Length 3 mm. Length of face, excluding mandibles, into width, including compound eyes, 1.1-3 times ("slightly" broader than long in *croceum*).

Antenna, 12 segments, scape and first segment of funicle shiny; the other funicular segments dull. Scape equal in length to first 4 segments of funicle (equal to first 3 segments in Smith's fig. 3 of male *croceum*). Reticulation of face with 10-12 polygonal areas between compound eye and median ocellus (5 in Smith's fig. 3 of male *croceum*).

Mesonotum with very narrow median carina; scutellum with similar but a more distinct carina (in *croceum* not distinct enough on mesonotum for mention). Metanotum with median, posterior spine as in *croceum*. Epinotum with its posterior vertical face two times as long as dorsal surface (more nearly equal in *croceum*, Smith's fig. 2). Median furrow of epinotum wide and shallow, most distinct on upper half of vertical face (in *croceum* more distinct on the base).

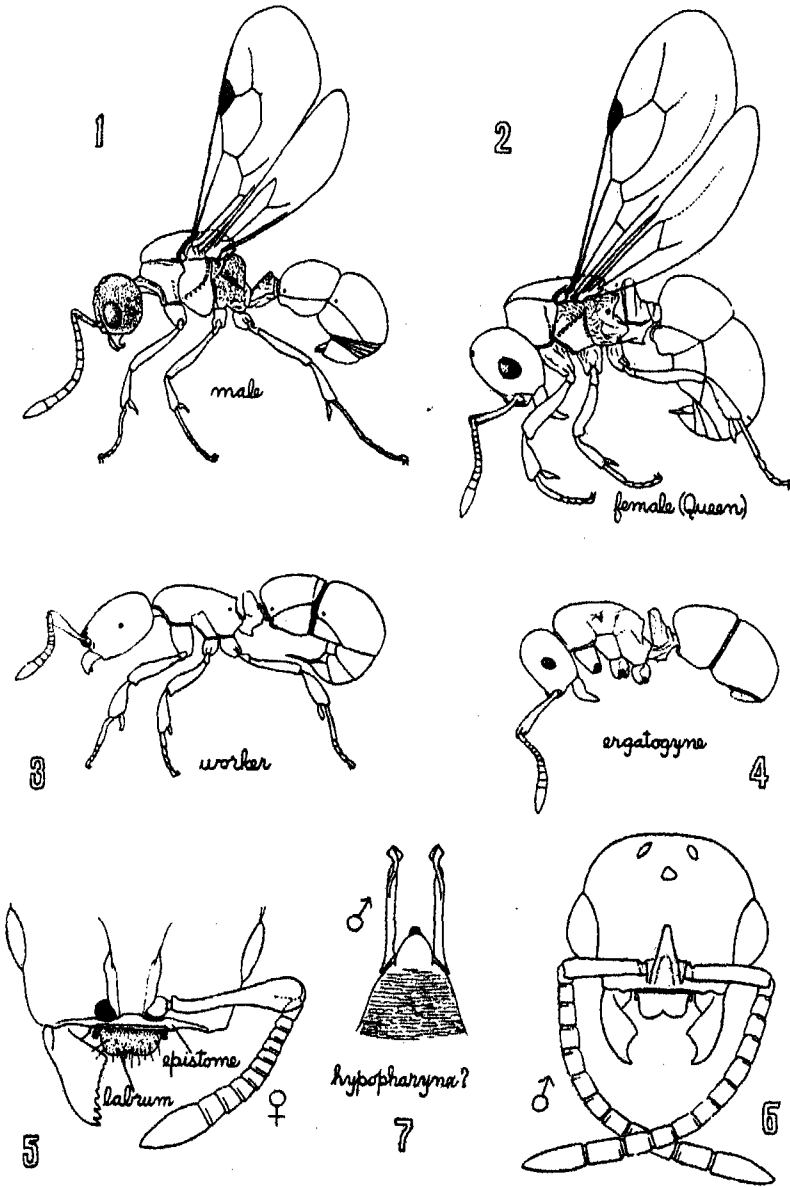
Color of head and body black; mandibles, antennae, and legs brown. Wings with colorless membrane and brown stigmas. (*Croceum* is ferruginous).

See Figures 1, 6, 8, 13, 15, and 21-26 which are drawn from regional material but from other nests than the male type nest.

Proceratium silaceum is a remnant from that time, barely a hundred years ago, when Ohio and Indiana were covered with an almost continuous forest. With the forest cover intact, drainage was much less rapid than now, so that much of the wooded area was more moist the year around. In those areas supporting white and burr oaks this species of ant was probably to be found in every oak log which, at a late stage of decay, had the proper moisture content.

Collection Records

Proceratium silaceum is sparsely listed in the literature because it is a rare ant which is never taken abundantly. Roger described it in 1863 (pp. 171-172), basing his description on one worker, which he lists as from North America. It has subsequently been collected along the eastern and southern parts of the United States.



Figs. 1-7.

The present paper concerns *P. silaceum* gathered from Ohio, Canada, and Tennessee. The collecting was done between 1930 and 1938, and during this time it was taken 16 times in Ohio, 9 times in neighboring parts of Canada, and 4 times in Tennessee. Most of the collections were made in the region of western Lake Erie over the islands and mainlands which surround Gibraltar island. This territory includes Ottawa County in Ohio and a part of Ontario, Canada. From Ontario the following collections are recorded: Middle Island (7-13-34 C. A. Dennis), Pelee Island (7-25-30 R. Wolf; 8-19-30, 8-23-30, 7-18-31, 8-18-31, 8-25-36 M. T.; 8-25-38 M. E. Amstutz), Point Pelee (8-5-31 C. H. K.). From Ottawa County, Ohio, are the following: South Bass Island (8-14-31 M. T.), Kelley's Island (8-18-35 C. A. Dennis), West Sister Island (7-18-36 C. H. K.), Catawba (7-10-31 S. R. Williams; 7-11-35 M. T.).

Other collections in Ohio show that the ant is rather widely distributed throughout the state. Records are as follows: in north central Ohio from Huron County (8-22-31 C. H. K.), in northeastern Ohio from Ashtabula County (8-29-38 A. E. Headley), in central Ohio from Franklin County (9-1-36 C. H. K.), Delaware County (6-5-38 C. H. K.), and Madison County (9-7-31, 9-25-31 C. H. K.), and in southern Ohio from Adams County (9-1-31 C. H. K.), Pike County (6-14-32 C. H. K.; 2 collections, no date, M. Schramm), and Meigs County (1 collection, no date M. Schramm).

The Tennessee records are from Blount County on the eastern edge of the state (9-15-31, 9-12-32, 9-17-32, 4-21-33 C. H. K.).

Since these scattered records extend over a period of intensive collecting by the authors and include the combined efforts of a number of other people, they tend to substantiate the evidence that *Proceratium silaceum* is truly a rare ant, not abundant in any habitat.

Ecological Distribution

The conditions under which the ants live are remarkably similar. Seemingly they possess very little toleration for variation in habitat. In every case they have been found in logs or stumps large enough to retain moisture, and in such a state of decay that the wood can be picked apart with the fingers or is already in fine, loose, soil-like granules. White oak logs seem to reach this state in the most perfect fashion, and most of the ants have been collected in this wood, but they have also been found in pine, elm, and burr oak logs in similar condition.

The logs must not only be well decayed but they must lie in a place where moisture is plentiful and constantly maintained. Other environmental factors in the surroundings may vary considerably. On Pelee Island and the neighboring mainland of Point Pelee, logs containing nests were found on sand of richly vegetated pine or oak dunes. Here the sand is subirrigated by the lake. Collections were also made from logs lying on loam in woods of various types of vegetation: elm-maple woods on Pelee Island, oak-maple woods on South Bass Island, hackberry woods on Middle Island, and oak-hickory woods at Willard (Huron Co., Ohio). These were usually deep, moist woods, in most cases near a river, lake, or bog. Thus the substratum may vary from sand to loam

and the type of vegetation may be quite diverse, but conditions must be such that large logs are kept thoroughly and constantly moist, and the logs must be in an advanced state of decay.

Nest Conditions

One of the aggravating things about collecting *Proceratium* is the fact that frequently a single individual is found, and then no amount of hunting will reveal the nest. In only 16 cases were nests actually found. One such, containing an unusually large colony of 60 workers, 73 males, 1 dealate female, and larvae and pupae, was collected on Pelee Island under rather typical conditions. The large white oak log, lying near the top of a small, completely vegetated white oak dune just back of the sand plain on the south spit of the island, was overgrown with wild grapes and poison ivy and was partially shaded by young trees. It was red and soft enough to be broken easily with the fingers in most places, although it retained its shape throughout. The ants were in an unusually soft part in the upper half of the log. They had small galleries following the annual rings of the wood. The workers were almost the color of the wood, and, since they moved slowly or remained curled up motionless, they were hard to see. The black, active males were quite conspicuous. In the same log were nests of *Ponera coarctata pennsylvanica* Buckley, *Myrmecina graminicola americana* Emery, *Strumigenys pergandei* Emery, *Aphaenogaster fulva aquia picea* Emery and *Camponotus herculeanus pennsylvanicus* De Geer.

Nests seem to be most frequently located in the soft wood which is just stiff enough to retain its shape but which is near an area of loose granular decay. Usually the nest is a small cavity 2.5 to 3 mm. long and .5 to 1 mm. wide with one or more slender galleries leading out from it and extending between the slightly harder circles of spring growth of the annual rings. Colonies are usually small; perhaps the one which contained 28 workers may be considered average.

Larvae and pupae were found from the beginning of the collecting season (July) until its end (September); so no data were gathered as to when they are first produced in the spring or whether they wintered over. Pupa cases are delicate enough that the pupae may be seen within them. They are white and only slightly elongated, not yellow and long as are those of the other two local *Ponerinae*, *Ponera coarctata pennsylvanica*, and *Stigmatomma pallipes*. They are about 1 mm. wide and 2.5 mm. long. Callows, newly emerged, are a very light straw color. Males and winged females probably emerge near the first of August (our earliest record for collecting them is 8-7-31). They are still in the nest in early September. Workers are entirely hypogaecic and have never been found in the light.

Associated Ants

Other ants, such as *Ponera coarctata pennsylvanica*, *Myrmecina graminicola americana*, *Stenamma brevicorne* Mayr, and *Strumigenys pergandei* or *pulchella* Emery, are frequently found associated with *Proceratium silaceum*. The colonies are never actually living together

but occur in different parts of the large moist logs which form the preferred niches of these species. However, the associated ants are not nearly so closely restricted in their nesting sites as is *P. silaceum*, since they are found in more varied habitats and are more abundant and widespread. Often ants of a wider range of habitat toleration are also found in the logs: *Camponotus herculeanus pennsylvanicus*, *Aphaenogaster fulva aquia picea*, and *Lasius umbratus mixtus aphidicola* Walsh. The logs are good niches for almost any kind of wood-inhabiting ant except such forms as *Crematogaster* and varieties of *Camponotus caryae* Nyl., which regularly nest in hard, dry wood.

Variations

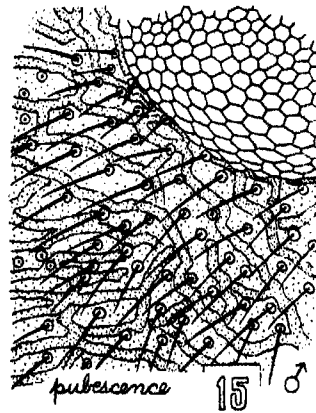
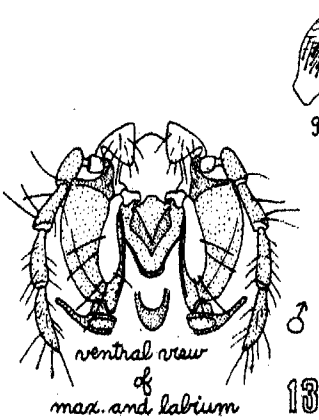
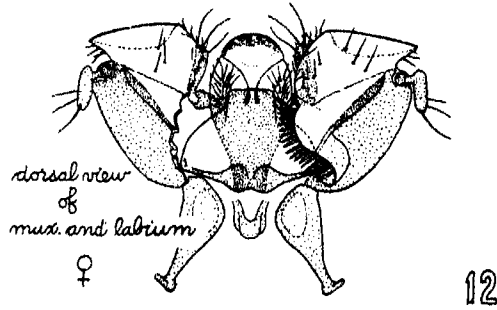
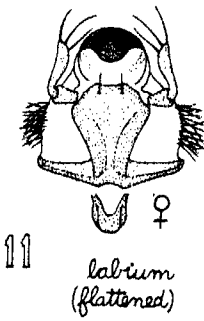
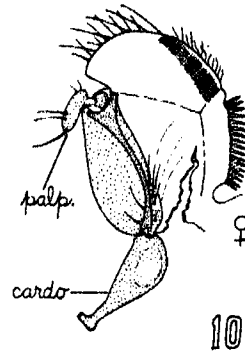
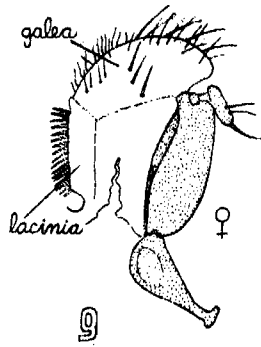
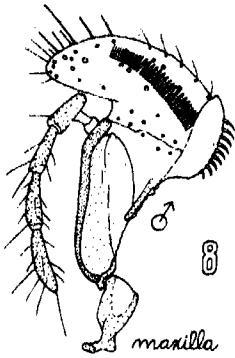
Three collections contained ants which were darker than the others. These were: (1) a large colony of 55 workers with one dealate female and one ergatogyne (Fig. 4), taken by C. H. K., No. 2618 (6-5-38) in Delaware County, Ohio, in a red, rotten white oak log lying in a shady second growth woods beside Big Walnut Creek; (2) a colony of 25 workers and one dealate female, taken at Catawba by M. T. (7-11-35) in a stump, with wood soft enough to come off in layers, lying under dense trees of an oak-walnut woods; (3) a single worker taken at Catawba by S. R. Williams (7-10-31) from unknown habitat. These answer Wheeler's description of *P. silaceum* subsp. *rugulosum* (from Wyandotte, Ind.) in that they are uniformly darker and more opaque than the other *P. silaceum* seen. However, they could not be distinguished by any uniform intensity of rugosity or any definite anatomical variation from the species. Whether they should be considered as being *silaceum* or Wheeler's Indiana subspecies cannot be decided until they are compared with type specimens.

Structure

The normal male, queen, and worker are shown in Figures 1-3. *Proceratium* belongs to the very primitive subfamily Ponerinae, many of which are distinguished by the groove between segments 1 and 2 of the gaster (abdominal segments III and IV). See Figures 1-4 and 16. The genus is further peculiar in the differentiation of the gaster into two regions. See Figures 16 and 17. Abdominal segments III and IV (Segs. 1 and 2 of gaster) are well developed and form most of the visible abdomen but tucked in the apex of abdominal segment IV is a post-abdomen of abdominal segments V to X which usually points cephalad but can be completely retracted into segment IV. This is similar to the anatomy of the higher flies (example, the house fly) but has evolved independently.

The eyes are large in the queen and male but are minute in the almost blind worker (Fig. 3). In the ergatogyne (Fig. 4) they are intermediate in size.

The ergatogyne is not found regularly in *Proceratium* nests but appears to be one of nature's genetic accidents. The latest evidence (Wheeler, 1937) is that the ergatogyne is a genetic mosaic of the worker and queen castes. We have found these in but one nest, Kennedy coll.,



Figs. 8-15.

No. 2618 (Delaware County, June 5, 1938). This nest contained a normal dealate nest queen, the ergatogyne with undeveloped wing stubs, which is figured (Fig. 4), and two workers with eyes slightly larger than those of other workers but no wing development. In the same nest were 55 normal workers. This was a nest of the slightly larger, darker form which on comparison with types may prove to be *rugulosum* Wheeler (1915). The type material of *rugulosum* was collected by Dr. W. S. Blatchley at Wyandotte, Indiana.

The mouthparts are shown in detail because they are so minute in an ant 2-3 mm. long that they have been little studied and seldom figured for ants so small. Figures 5 and 6 show the labrum, which the ant keeps folded into the mouth. The mandibles of the male (Fig. 6) are without teeth as compared with those of the worker or of the queen (Fig. 5). What is probably a hypopharynx (Fig. 7) dissects out of the floor of the mouth of the male. It may occur in the female castes but was not found.

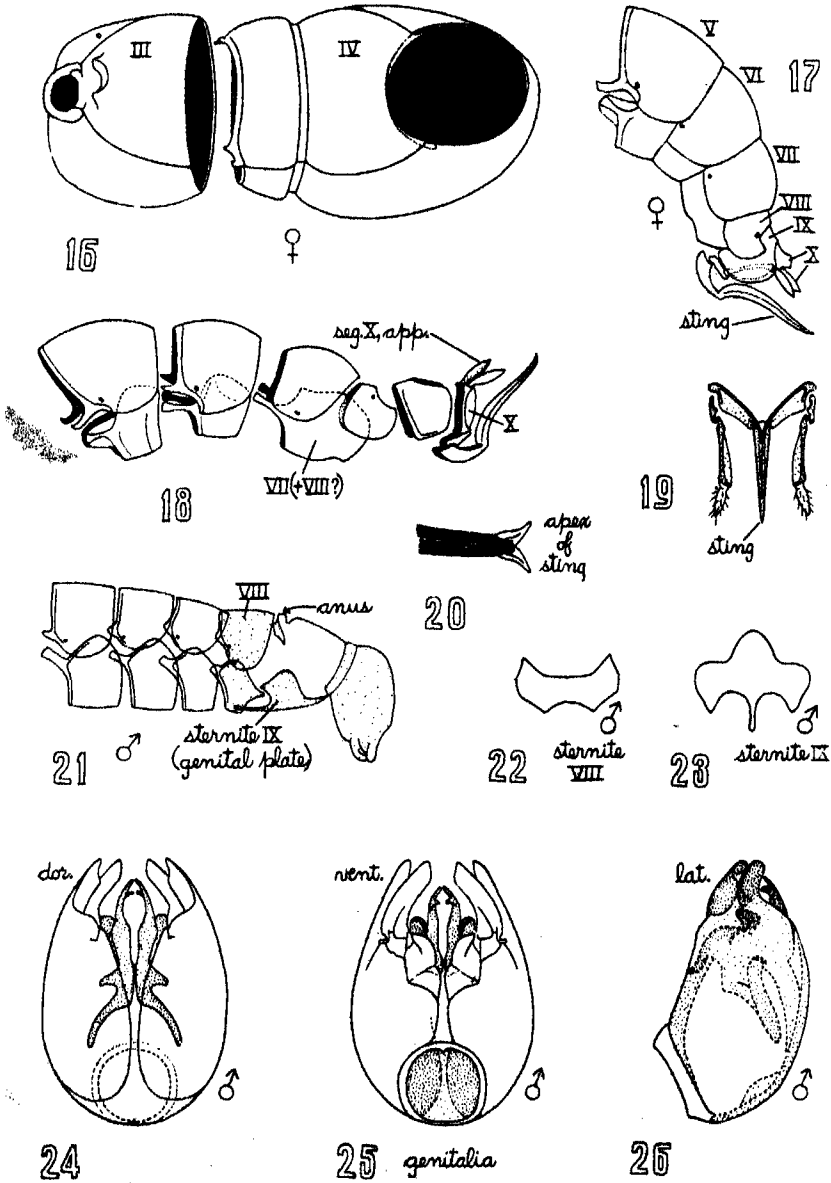
Figures 8, 9, and 10 are views of the maxilla, of male (Fig. 8), and queen (Figs. 9 and 10). The maxillary palp in the male is four-segmented, while in the queen and workers it has one segment. On the galea, revealed by transmitted light, is a comb-like series of sense organs. This is termed the "maxillary comb"; in the male it has 25 to 30 parts, while in the queen there are about 40. In larger ants these organs appear to be rigid hairs lying tight against the inner surface of the galea. Here they appeared to be more deeply embedded and less like free hairs. We have shown them, as seen by transmitted light, in Figures 8 and 10 and did not determine whether they were more closely associated with the internal or with the external surface of the galea. In Figure 9 the maxillary comb has been omitted to show better the hairs on the inner surface of the maxilla.

Figures 11, 12, 13, and 14 show the labium in the male and queen. In both the palpus is two-segmented. The inner surface is well supplied with long bristles (Figs. 11 and 14).

Figure 15 is a view at high magnification of the size of the pubescent hairs, showing their spacing as compared with the size of the ocellae of the compound eye. The area figured is between the eye and the base of the antenna of that side. We have been trying to develop some method of figuring the surface texture, pubescence, longer hairs, etc., of ants, as these items are used so extensively in describing species. The written terms are so susceptible of more than one interpretation. The checking by a figure of these parts against the size of the ocellae of the compound eye is one method of making a more accurate record of size and spacing of the pubescence.

The sting of the female (queen) is shown in Figures 17 to 20. The pair of cercus-like organs are considered appendages of segment X and are not cerci or appendages of segment XI. Before it has been lost by use, the apex of the sting bears a bifurcate membranous cap (Fig. 20).

Segments VII-X are highly modified in the female. Apparently the sternite is missing from segments VIII, IX and X. The sternite of segment VII is twice as long as those of segments V and VI, which suggests



Figs. 16-26.

that it may be double or a fusion of the sternites of segments VII and VIII. Notice the high position of the spiracle on segment VIII.

In the male (Figs. 21-26) the first highly modified segment is segment IX, where the tergite is reduced to a mere sliver in front of the anus, and the sternite is developed into a genital plate (Figs. 21 and 23). The latter is usually of a slightly different shape for each species of ant but to be studied has to be dissected out of the male. Figures 24-26 show three views of the male genitalia. The internal pair of slender forked parts (Figs. 24 and 25) are probably sagittae. The outermost pair of unstippled prongs are probably stipes.

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The Development of a Second Generation of the European Corn Borer, *Pyrausta nubilalis* Hbn., in Indiana

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When the European corn borer first entered Indiana in 1926, this insect was distinctly a one brooded form. Since that date, occasional traces of a second generation have been noted from time to time, but it was not until 1935 that sufficient second-generation borers were found to indicate a distinct trend toward a definite second brood of economic importance. During the past three years, the number of second generation borers produced has been so great as to become an important factor in corn borer increase. This transition of the borer to a two-generation form will alter several phases of the corn borer problem which up to the past three or four years have been thought of as being practically stabilized.

Pupation

Information on the pupation of the first generation larvae is fragmentary during the period up to 1935. In 1935 the first pupae were found in the field in DeKalb County, in sweet corn, on August 7; in 1936, on July 21; in 1937, on July 20; and in 1938, on July 14. Contrary to the development of pupation among the over-wintering larvae, the pupation of those larvae which provide the second brood occurs rather abruptly and apparently affects only the early larvae of the first generation.

In 1938 in Allen County, second brood pupation began on July 14 and was complete by August 8, a period of 20 days. In 1937, pupation began on July 30 and was complete on August 8, a period of 19 days. These periods, denoting the time when pupae are present in the field, are much shorter than the time required for the over-wintering larvae to pupate.

TABLE I.—Figures Showing the Percentage of First Generation Larvae Which Pupated in Dent and Sweet Corn in DeKalb County in 1938.

Sweet Corn		Dent Corn	
Planting Date	Per Cent of Borers Pupated	Planting Date	Per Cent of Borers Pupated
April 29	16.1	May 6	7.5
May 6	14.1	May 7	7.0
May 7	8.5	May 11	6.3
May 10	2.0	May 21	3.0
May 27	2.0	May 27	1.0
June 6	3.0	June 8	0.0

The fact that only the earliest larvae of the first generation pupate has been rather clearly indicated by the increased proportion of borers which have pupated in early dent or sweet corn fields as compared to the number pupating in later fields which receive only those eggs which were laid late in the first generation moth flight (Table I).

The percentage of larvae pupating to provide a second brood is variable not only in different fields but also in different localities. The highest rate of pupation has been found in early sweet corn fields, these being the locations in which the earliest eggs of the first generation moths are most frequently laid. Exceptionally early and vigorous dent corn fields also frequently show correspondingly high rates of pupation because of the influence of the height of the corn in attracting the first moths for the purpose of oviposition, but few dent corn fields have been examined in which the borers show as high a rate of second generation production as do early sweet corn fields.

The general trend toward an increased rate of second generation production in the more southerly locations of the borers distribution has been shown by examinations of fields from Steuben County southward to Wayne County (Table II).

TABLE II.—Percentage of Borers Pupating in Seven Counties in Indiana From Steuben County in the North, Southward to Wayne County. Fields Selected Were the Earliest Available.

County	Per cent Pupating in Early Sweet Corn	Per cent Pupating in Early Dent Corn	Mean
Steuben.....	2.10	2.00	2.05
DeKalb.....	16.10	7.00	11.52
Allen.....	8.00	14.5	11.25
Adams.....	8.00	19.5	13.75
Jay.....	11.11	19.6	15.30
Randolph.....	18.00	.....	18.00
Wayne.....	19.64	.....	19.64

The rate of pupation in Steuben County was 2%, and in Wayne County it was 19.64%. Other counties located between these localities showed intermediate degrees of second-brood production. These figures, while varying somewhat in individual fields, tend to indicate a transitional area in central Indiana in which the European corn borer is changing its seasonal development to provide for a whole or partial second generation.

Moth Flight and Emergence

The use of light traps during the past four years, to determine the period of actual moth flight, has shown a variable period of flight of first- and second-generation moths, both from the point of view of the time of flight and the duration of flight. The beginning of first-generation flight has varied from June 7 in 1938 to June 28 in 1935, and the

end of the first flight has varied from July 16 to July 23 during the same years. The duration of flight was longest in 1936, when moths were captured at lights over a period of 37 days.

The second-brood flight has varied in its first appearance from July 26 in 1938 to August 4 in 1937, and the duration of active flight in those years when sufficient moths were captured to indicate a well defined second brood has varied from 20 days in 1937 to 47 days in 1938. Weather conditions which favor or inhibit the length of life of the moths has made the flight periods either very short or, as in 1938, very long. Since emergence was complete on August 8 in Allen County, where the light

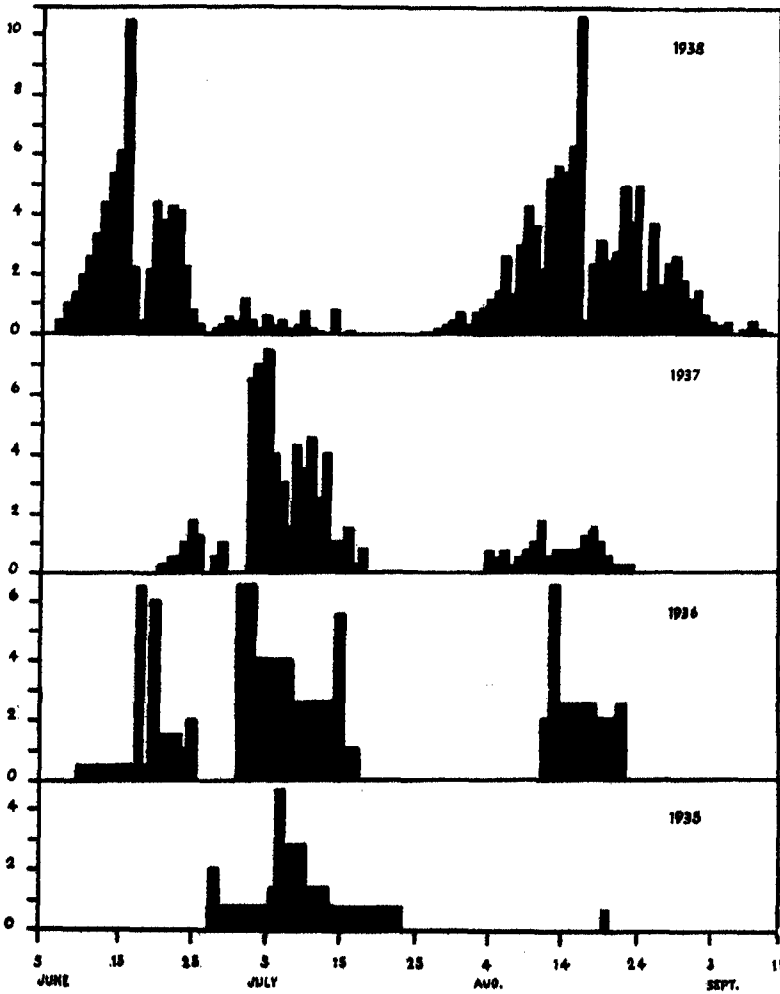


Fig. 1. Trend of moth flight as determined by light trap captures; 1935, 1936, 1937, moths per trap; 1938, moths per trap divided by two.

traps were situated in 1938 and where emergence was being observed, individual moths must have been in flight for a period of at least 34 days.

The proportion of first- and second-generation adults caught in light traps has varied from one second-generation moth to 23 first-generation moths in 1935, from one to 2.31 in 1936, and from one to 4.35 in 1937; and in 1938 the proportion of second brood adults to first generation was reversed and was 2.64 to one (Fig. 1). These figures do not necessarily indicate more moths in flight during the second than during the first generation, as the moths were in flight for a longer period of time during the second brood and the distance from which these moths drifted in to the lights could not be determined. With the longer period of flight after the completion of emergence, larger numbers undoubtedly drifted in from greater distances than in the first brood. In the first generation, moth flight ended 12 days after the completion of moth emergence, while in the second brood, moths continued to fly for 34 days after the last record of moth emergence in the field. Years of early first-generation moth emergence tend to show a higher degree of second-brood production by the European corn borer than do those years in which the emergence of the first brood has been delayed by seasonal climatic conditions.

Winter Mortality

The winter mortality of second-generation borers will be variable from year to year, depending on the stage of development in which the larvae go into the winter. This depends on the time at which the eggs are laid and the seasonal conditions in the fall which will permit the larvae to become mature. In 1935, second-generation larvae did not become mature before cold weather, and the winter mortality of second-generation borers averaged 98% in DeKalb County. During 1936 and 1937, moth flight and oviposition were complete by August 20, and the borers became full grown by cold weather. During these years the winter mortality was no greater than among first-generation larvae and was about normal. During the 1938-1939 season, a heavy winter mortality of second-generation borers may be anticipated as egg laying continued to September 11, and borers resulting from such late eggs will have little chance of becoming mature enough to pass the winter successfully.

Host Preference

So far as is known at the present time there has been little tendency for the second-generation moths to select host plants other than corn for oviposition. A single host other than corn was found during 1938 to be infested by the second-generation borers; this was gladiolus. Late corn is preferred to early corn by the second-generation, and many late fields carry higher borer populations, as a result, than do early fields. Populations of four plantings of dent corn, in experiments at Auburn during 1938, had populations ranging from 14 borers per 100 plants in corn planted on May 12 to 46 borers per 100 plants in corn planted on June 8. This condition was first noted in sweet corn plantings made in 1936, when sweet corn planted in five plantings between May 7 and June

14 had the following borer populations per 100 plants: May 7, 27.19; May 14, 17.02; May 28, .88; June 7, 0; and June 14, 21.48. Extremely early and extremely late plantings tend to carry the heaviest borer populations. This is particularly true of those fields in the southern area of infestation.

Discussion

The development of a second brood of corn borers in Indiana is important from the point of view of several factors. Heavy flights of second brood moths tend greatly to build up over-wintering populations and provide an increased abundance of borers for the succeeding season. Late-planted corn, which heretofore has been practically immune from corn borer, will be, and is being attacked. While the greater part of the second generation of borers became full grown too late in the season to reduce greatly the yields of dent corn, late sweet corn may be damaged to a severe extent. The additional flight of moths, which occurs when weather conditions are normally more conducive to longer life than earlier in the season, will undoubtedly hasten the spread of the borer to new territory and tend to build up populations more rapidly on the margins of the known infested areas. The possibility of an increase in the number of host plants is also an important consideration from the point of view of the damage the corn borer will do to such hosts and also from the greater difficulties encountered in effecting a satisfactory control where infestations might occur in host plants other than corn.

Radiation of *Drosophila melanogaster* with Low-Intensity Ultra-Violet Light for One Complete Generation. I. Effect on Crossing-Over in the Second Chromosome

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Introduction

Considerable work has been done concerning the effects on *Drosophila* of treatment with X-rays, heat, and radium. This includes production of mutations and modifications of the rates of non-disjunction and crossing-over.

In recent years the effect of ultra-violet radiation has been investigated in some degree. Altenburg studied the production of mutations by unfiltered ultra-violet radiation. Promptov induced mutations by monochromatic ultra-violet radiation. Rifenburg modified crossover rates by treatment with monochromatic ultra-violet light. All these investigators used relatively heavy doses for short periods.

Since no work had been published on the effect of radiating *Drosophila* with ultra-violet light for long periods, this work was undertaken to study the effect of unfiltered radiation for a complete generation on crossing-over in the second chromosome of *Drosophila melanogaster*.

Review of Literature

1. **Effect of X-radiation.**—Mavor (1923) reported from a series of experiments on X-radiation that X-rays caused a decrease in crossover values between White and Miniature either by inhibiting crossing-over or by increasing double crossovers.

Later Mavor and Svenson (1924) investigated the effect of X-rays on crossing-over in the second chromosome. Treated females heterozygous for Black-Purple-Curved were backcrossed to recessive males with the following results: (1) crossover value between Black and Purple 3.77% in controls and 16.67% in the experimentals, (2) crossover value between Purple and Curved 17.38% in controls and 30.58% in the experimentals. This was a very significant increase in crossing-over in the case of the X-rayed mothers.

Muller (1925) published results of work with X-radiated autosomes. He found in both long autosomes a regionally differentiated susceptibility to X-rays, with the maximum susceptibility in the morphologically differentiated portion at or near the spindle-fiber attachment. The second and third chromosomes reacted similarly—that is, with an increase of crossing-over in this region.

II. *Effect of Radium.*—Plough (1924), working with treated females heterozygous for Black-Purple-Curved backcrossed to pure recessive males, found that the beta and gamma rays of radium caused an increase in crossing-over.

III. *Effect of Heat.*—Plough (1917) reported results from an experiment on the effects of temperature and environment. Extreme heat and cold, acting upon females up to the time of hatching, caused a decided increase of crossover percentage in the second chromosome for the first ten day broods. He found no effect of high and low temperature on crossing-over in the first and third chromosomes.

He (Plough 1921) studied the effect of heat on flies heterozygous for autosomal genes. The following results were obtained: (1) there was no significant increase in the percentage of crossing-over in the second chromosome as a result of the exposure of developing eggs to high temperature; (2) in the third chromosome there was an increase in the region of the spindle-fiber attachment only; (3) crossing-over varied with the age of the female but in those regions only which showed a reaction to temperature.

Stern (1926) raised experimental females at 30° C. and controls at 25° C. He obtained an increase in percentage to 16 in the experimentals against 11½ in the controls. This was in the Bar-Bobbed region of the first chromosome, which is near the attachment of the spindle-fiber.

Schwab (1935) made a further study of effect of temperature on crossing-over. Under high temperature there was increased recombination in the third chromosome which was found to be concentrated between Scarlet and Pink (the area of the spindle-fiber attachment) and spreading with high decrement to the adjacent regions. This result agrees with those reported by Muller for X-rays and by Bridges for age.

IV. *Effect of Ultra-Violet Light.*—In this laboratory Rifenburgh (1935) treated virgin females, heterozygous for Black-Vestigial-Brown, with monochromatic ultra-violet light and backcrossed them to Black-Vestigial-Brown males. With radiated adults, he obtained a slight increase in crossover percentage near the spindle-fiber attachment of the second chromosome. In the case of treated eggs and young larvae, there was a decrease in crossover percentage.

General Methods

The source of ultra-violet light for the following experiments was a General Electric Sun Lamp (S, Model K). In this lamp, the ultra-violet rays are produced by gaseous mercury heated to incandescence by a tungsten filament within a bulb of special glass. A silver-colored shield placed below the bulb reflects and diffuses the light so that the radiation is nearly uniform over a fairly wide area.

The radiated generation was reared in 100 cc. beakers filled to within an inch of the top with Purdue medium (Rifenburgh, 1933). A thin film of yeast was allowed to grow on the surface of the cultured medium before the flies were placed in the beakers. Since the medium tended to

shrink from the sides of the containers, water was added at frequent intervals. This prevented the females from laying their eggs in the crevices around the edge of the medium. Thus, the eggs were laid on the exposed surface. This assured radiation for every egg. Cellophane, held in place by rubber bands, was used for a covering. In the controls, a glass Petri plate in addition to the cellophane was used to shield the flies from the ultra-violet rays.

Since the temperature was increased by the lamp, a small fan was used which cooled the air around the beakers and kept the temperature down to approximately 27° C., which was 2° C. higher than room temperature.

Parents treated under the lamp and those used for controls were taken from the same stock bottles so that they would be of the same age, parentage, and physiological condition.

The female parents were pure Black-Vestigial-Brown virgins, whereas the males were taken from the Wild stock. The flies were mated, one pair to each beaker, were allowed to recover from etherization for a few hours, and then were placed under the lamp. They remained in the beakers until pupae appeared, then they were removed.

The offspring were collected at eight-hour intervals in order to insure virginity of the females. These females (wild in phenotype and heterozygous for Black-Vestigial-Brown) were backcrossed to males from pure stock and pairs were placed in regular wide-mouth mating bottles containing yeast-treated medium. These parents were allowed to remain in the bottles for four days after which they were removed.

The offspring of this backcross were examined, classified, and counted until eighteen days after mating.

From the data so collected, crossover percentages were computed.

Results

1. **Experiment 8.**—Virgin females homozygous for Black-Vestigial-Brown were mated, in beakers as described above, to males from the pure Wild stock and allowed to recover from etherization for a few hours. These beakers then were placed under the ultra-violet lamp at a distance of 37 inches. The parents were removed as soon as pupae appeared. When offspring emerged, the heterozygous Wild females were backcrossed to homozygous untreated Black-Vestigial-Brown males. The results of these mating are shown in Table I. From these results were calculated the crossover value which are shown in Table II and Table III.

2. **Experiment 9.**—This differed from Experiment 8 in two respects: first, the distance was increased to 47 inches; second, the room temperature during the second generation was about 27° C. instead of 25° C. as in Experiment 8.

The observed results are shown in Table I and the computed results in Table II and Table III.

Combined results of experiments 8 and 9 are shown in the same tables with the uncombined results.

TABLE I.—Emergence Record of Backcrosses by Phenotypes

No. of Experiment	Experimentals			Controls		
	8	9	8+9	8	9	8+9
Wild	3838	751	4589	4073	751	4824
Black-Vestigial-Brown	3558	633	10191	3706	655	4361
Black	691	164	855	530	135	655
Vestigial-Brown	608	224	720	454	101	555
Black-Vestigial	1541	112	1765	1327	260	1647
Brown	1728	338	2066	1548	293	1841
Black-Brown	177	34	211	87	20	107
Vestigial	168	31	199	88	11	99
Totals	12309	2287	14596	11880	2226	14106

TABLE II.—Crossover Percentage Between Black and Vestigial Loci.
(Region of Spindle-fiber Attachment)

Exp. No.	Experimentals			Controls			Difference	D P.E. (diff.)
	No. ♀ tested	Population	Crossover % B to V	No. ♀ tested	Population	Crossover % B to V		
8	58	12309	13.36 ± .207	70	11880	9.76 ± .272	3.60 ± .28	13
9	16	2287	14.91 ± .445	12	2226	11.99 ± .46	2.92 ± .65	4.1
8+9	74	14596	Increase 13.59 ± .196	82	14106	Increase 10.10 ± .057	3.49 ± .20	17.1

Map Distance=18.5 (Morgan 1932).

TABLE III.—Crossover Percentage Between Vestigial and Brown Loci.
(Remote Region)

Exp. No.	Experimentals			Controls			Difference	D P.E. (diff.)
	No. ♀ tested	Population	Crossover % V to Bw	No. ♀ tested	Population	Crossover % V to Bw		
8	58	12309	29.36 ± .278	70	11880	26.18 ± .270	3.18 ± .39	8.22
9	16	2287	27.42 ± .629	12	2226	26.24 ± .629	1.18 ± .69	132
8+9	74	14596	29.05 ± .241 Increase	82	14196	26.18 ± .244 Increase	2.87 ± .34	8.36

Map Distance=37.5 (Morgan 1932).

Discussion

In nearly every published record there has been reported an increase in crossing-over produced by treatment with X-rays, radium, heat, and ultra-violet light. The increase has occurred largely in the region of the spindle-fiber attachment (the region which is most susceptible to the effects of radiation).

In the sex chromosome, Mavor found that X-rays caused a decrease in the remote region, but he studied no near region in this chromosome. For the second chromosome he agrees with the others. Plough, Schwab, and Stern found that heat caused an increase in the region of the spindle-fiber attachment. In the Purdue Laboratory, an increase in crossover percentage was produced by ultra-violet radiation between the Miniature and Bar loci which is near the region of the spindle-fiber attachment. An increase also occurred in the remote region in treated individuals in this laboratory (unpublished work).

In the third chromosome some X-radiation and heat caused an increase in the near region (the region of greatest susceptibility).

In the second chromosome heat, radium, and X-rays caused an increase of crossing-over in the region of the spindle-fiber attachment. In the Purdue Laboratory experiments have shown a marked effect of ultra-violet radiation on increase in crossing-over.

Data obtained in this experiment indicate a definite increase in crossing-over percentage due to ultra-violet radiation in the second chromosome, the most striking increase being in the region of the spindle-fiber attachment. Statistical analysis made by dividing the difference by its probable error indicates that there is no question of these results being significant, factors of 17 and 8 being obtained whereas most statistical consciences require but 3.

Probably, in regard to modifying crossover values, ultra-violet radiation should be classed in importance with X-rays, radium, and heat.

Summary

The purpose of the experiments was to determine the effects of unfiltered ultra-violet radiation for a complete generation on crossing-over in the second chromosome of *Drosophila melanogaster* and specifically in the two regions limited by the Black, Vestigial, and Brown loci.

1. Definitely greater crossover values were found in the treated individuals than in the controls.

2. There is no doubt of the difference being significant, since it was more than 17 times its probable error in the Black-Vestigial region and over eight times its probable error in the Vestigial-Brown region.

3. These results are in agreement with those observed by investigators working with other kinds of radiation, who found an increase in crossing-over in treated flies, this being greater in regions near the spindle-fiber attachment than in remote regions.

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Radiation of *Drosophila melanogaster* with Low-Intensity Ultra-Violet Light for One Complete Generation. II. Effect on Crossing-Over in the First Chromosome

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Introduction

To date no work has been published indicating the effects of long-time ultra-violet radiation on crossing-over in the first chromosome and this work was undertaken in order to discover, if possible, these effects.

Previous Work Concerned with the Effect of Radition on Crossing-over in the First Chromosome

Mavor (1923) found a decrease in crossing-over in the White-Miniature region treated with X-rays.

Mavor (1929) treated females with X-rays in order to discover the resulting effects on non-disjunction and crossing-over. The females which were heterozygous for White-Long and Eosin-Miniature were radiated while still in the pupa stage. The anterior portion of the body of a number of females was exposed in one instance, the posterior portion of a number of others, and the entire body of others. Unradiated females were used as controls. He found that crossover values between the White and Miniature loci were significantly reduced in the offspring of the flies which were exposed entirely to the effect of X-rays and also in the flies which were treated posteriorly.

Investigators using first chromosome factors had found that the crossover values were reduced here in contrast to the increase found in the autosomes. Stern (1926) pointed out that the factors used by these workers were located at a distance from the spindle-fibre attachment and that if crossover increases were not found in the remote (from the spindle-fiber attachment) regions of the autosomes, then one should not expect increases in crossover values for the factors in the distal regions of the heterosomes. Accordingly, he exposed eggs heterozygous for Bar and Bobbed factors to high temperatures (30° C.) until the time of hatching, when they were transferred to 25° C. The offspring of the females exposed to high temperatures showed a significant increase in crossing-over (8.5 times the probable error) when compared to the controls which were kept at a constant temperature of 25° C. This increase disappeared about nine days after exposure. Stern explains the drop in crossover values by assuming that high temperature produces its effects upon crossing-over at the oögonial stage and does not effect germ cells that are in the oöcyte stage. Eggs laid seven or eight days after the removal of the females from 30° C. temperature had not yet reached the susceptible oögonial stage at the time they were subjected to the high temperatures.

Methods

The methods used were similar to those of Rifenburgh and Paradise (1938), a General Electric S2 sun lamp being used from the time of mating the P's until the F₁'s emerged, at a distance of forty-eight inches.

The female parents were virgins from the stock of Yellow-White-Miniature *Drosophila*. The male parents used were of pure Bar stock. One male and one female were put into each beaker and after the flies had been given sufficient time to recover from the effects of etherization, the beakers were placed under the lamp. These parents were allowed to remain in the beakers until larvae appeared and then were removed.

The offspring were irradiated during their entire life history until the time of mating. The female offspring were heterozygous for all four pairs of factors and Bar in phenotype, but, since the factors were sex-linked, the male offspring were homozygous recessive.

The irradiated Bar females were removed at 8-hour intervals in order to assure their virginity. The males were discarded or used for back-crossing.

The females were back-crossed to Yellow-White-Miniature males which were the quadruple recessives, Bar being a dominant factor.

The parent flies were left in the original bottles for four days, then transferred to a new bottle for another four-day period, and then re-transferred to a third bottle for still another four-day period. It was expected that more offspring would be produced by one female in a series of bottles than she would produce normally if left in only one bottle for the egg-laying period.

The offspring were counted on the eleventh, fourteenth, and seventeenth days after the parents were placed in the bottles. Classification was made as to phenotype and sex.

Results

Eighty-six matings of experimentals were made. Fifty pairs were transferred at the end of four days to new bottles where each remained for another four-day period before being transferred to a third bottle.

Fifty-five control matings were made of the non-irradiated Bar females. Forty pairs were transferred to second and to third bottles.

The 176 experimental bottles produced 18,174 flies which were distributed among the phenotypes as follows:

4263 Bar	7 Yellow-Miniature
5526 Yellow-White-Miniature	292 Miniature-Bar
116 White-Miniature	2001 Yellow-White
93 Yellow-Bar	0 White-Miniature-Bar
2618 Miniature	17 Yellow
1067 Yellow-White-Bar	6 White
1368 Wild	1 Yellow-Miniature-Bar
697 Yellow-White-Miniature-Bar	
2 White-Bar	18174

The 185 control bottles produced 2793 flies which were distributed among the phenotypes as follows:

688 Bar	3 Yellow-Miniature
825 Yellow-White-Miniature	47 Miniature-Bar
11 White-Miniature	337 Yellow-White
19 Yellow-Bar	0 White-Miniature-Bar
396 Miniature	4 Yellow
161 Yellow-White-Bar	3 White
205 Wild	0 Yellow-Miniature-Bar
94 Yellow-White-Miniature-Bar	
0 White-Bar	2793

Crossover percentages for the three regions of the chromosome were calculated. The values are tabulated in Tables I-II-III.

TABLE I.—Crossover Percentage in the First Chromosomes of Females Between Yellow and White Loci

Experimentals			Controls			Difference	D
Number of Matings	Total Population	Crossover % Y to W	Number of Matings	Total Population	Crossover % Y to W		P.E. (diff.)
176	18174	1.33 ± .0513	135	2793	1.432 ± .1524	Decrease 100 ± .163	.615

Map Distance 1.5 Morgan (1932).

TABLE II.—Crossover Percentage in the First Chromosome of Females Between White and Miniature Loci

Experimentals			Controls			Difference	D
Number of Matings	Total Population	Crossover % W to M	Number of Matings	Total Population	Crossover % W to M		P.E. (diff.)
176	18174	32.981 ± .744	135	2793	33.962	Decrease 981 ± .910	1.08

Map Distance 34.6 (Morgan 1932).

TABLE III.—Crossover Percentage in the First Chromosomes of Females Between Miniature and Bar Loci (The Region of Spindle-fiber Attachment)

Experimentals			Controls			Difference	D
Number of Matings	Total Population	Crossover % M to B	Number of Matings	Total Population	Crossover % M to B		P.E. (diff.)
176	18174	24.111 ± .068	135	2793	21.124 ± .402	Increase 2.981 ± .408	7.321

Map Distance 20.9 (Morgan 1932).

Discussion

The results of this experiment show a slight decrease in crossover percentage between the Yellow and White loci. This decrease was not significant, being less than its probable error. This Yellow-White region

has a map distance of only 1.5, and, because of its extreme shortness, it must be rather resistant to changes in amount of crossing-over.

In the White-Miniature region the experimentals show a decrease in crossing-over as compared with the controls, but, again, the decrease is not significant. Rifenburgh (1935) used these same loci and found that ultra-violet light of high intensity caused an increase in crossing-over in offspring of females radiated as pupae but a decrease in offspring of females radiated as adults.

Working with X-rays, Mavor found a decreased crossover percentage for the White-Miniature region. He attributed this decrease to a crossover inhibitor developed by the X-rays or to increased double crossing-over which he could not measure since his experiment involved only two loci.

The increase in crossing-over between the Miniature and Bar loci is somewhat unexpected in the light of Mavor's and Rifenburgh's work. However, neither of these workers used a region so near the spindle-fiber attachment as this. The increase is significant, being 7.3 times the probable error. These results indicate that the effects of radiation must be much the same as in the autosome.

Early workers used loci at the left end of the first chromosome and found decreased crossover percentages, leading them to believe that the sex chromosome and the autosomes were opposite in reaction to the effects of X-radiation. Later it was found that the increase in crossing-over in the autosomes was limited to the region near the spindle-fiber attachment and that the regions near the ends of the autosomes were resistant to changes resulting from radiation.

Muller, Plough, and Schwab each have conducted experiments with third chromosome characters which range from the Roughoid locus at 0.0 to the Claret locus at 100.7, and they agree in finding an increase of crossover percentage near the attachment of the spindle-fiber only. Mavor, Muller, and Plough each subjected flies with second chromosome characters to radiations, and again each found crossover increases near the center of the chromosomes only.

Stern used Bar-Bobbed factors of the first chromosome in measuring effects of temperature on crossing-over in this region, which is near the attachment of the spindle-fiber. He found a significant increase, and this led him to believe that the crossing-over mechanism was susceptible to change near the point of the spindle-fiber attachment only.

The present work with ultra-violet irradiation involving loci scattered almost the entire length of the first chromosome seems to corroborate the work of both Mavor and Stern. Regions distant from the spindle-fiber attachment showed decreases in crossing-over that were, however, not significant, whereas the region nearest the spindle-fiber attachment showed an increased crossover percentage.

Comparison of the results reported in this paper with work of Mavor, Muller, Plough, Rifenburgh, Rifenburgh and Paradise, and Stern seems to indicate that, in general, electro-magnetic radiations cause an increase in crossing-over in the various chromosomes which is most pronounced near the points of spindle-fiber attachment.

Summary

This work was undertaken in order to discover the effects of long-time low-intensity ultra-violet radiation on crossing-over in the first chromosome of *Drosophila melanogaster*. The regions tested were between the Yellow and White, White and Miniature, and Miniature and Bar loci.

1. No significant effects on crossing-over between the Yellow and White and between the White and Miniature loci were found.

2. Crossing-over in the Miniature-Bar region was significantly increased.

3. These results agree with the results of other workers with other types of radiation, who found that crossover increase occurred principally or entirely near the point of spindle-fiber attachment.

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A Note on the Occurrence of the Spotted Turtle, *Clemmys guttata* (Schneider) in Indiana

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In May, 1938, a male specimen of the spotted turtle, *Clemmys guttata*, was collected from a small creek near Logansport, Indiana. According to Cahn (1937), the geographic distribution of this species extends from the Atlantic seaboard westward to Illinois and Wisconsin. Hay (1891) reported its occurrence in Indiana "only in the northern portion among the numerous lakes, streams and swamps found there." He mentioned Dr. G. M. Levette reporting it first from Kendallville but did not give the source of his information. Two specimens were taken by members of the Indiana Academy of Science at Lake Maxinkuckee in 1891. Other collectors mentioned by Hay were Dr. V. Gould, Rochester, and Dr. Baur at English Lake. The present report is the only record of a spotted turtle collected south of Lake Maxinkuckee. The westernmost limits of its distribution appears to be in southern Wisconsin and near the Indiana-Illinois boundary. Higley (1889) reported it from Walworth County, Wisconsin; and more recent records by others indicate its common occurrence in the southern part of this state. Cahn collected two specimens from the western end of Wolf Lake, Cook County, Illinois.

The present specimen agrees with Cahn's description of *C. guttata* with but one exception. He described the claws as follows: "All five of the digits of the fore limb with claws; hind limbs with only three digits bearing claws." In our specimen the five digits of the fore limb and four digits of the hind limb bear claws. Cahn gave measurements of only two females; but since his description of the species was based on the study of several individuals, the difference in claws does not seem to be a sexual character. According to Cahn, the number of orange spots on the carapace is about sixty. Sixty-one were counted on the present specimen.

The following table affords a comparison of the writer's specimen (3) with two spotted turtles (1 and 2) described by Cahn (1937). All measurements are in millimeters.

Carapace		Plastron			Head	Tail		Sex
Length	Width	Length	Width	Depth		Total	A-T	
(1) 109	87	99	71	40	16	26	20	female
(2) 114	76	95	63	40	16	31	25	female
(3) 113	104	85	50	45	16	26	20	male

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Banding Studies of the Blue Jay

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In central Indiana the Northern Blue Jay (*Cyanocitta cristata cristata*) is a conspicuous and common bird of town and country. It frequents the vicinity of habitations, nesting during April, May, and June, and appears to remain in the immediate neighborhood the year round, for it is about equally abundant both winter and summer. Whether it really migrates more or less and how much it wanders in a given locality can be determined definitely only by banding studies. These problems as they relate to the birds of this immediate region, together with certain remarks on longevity, form the basis of this paper.

In the 14 years, from December, 1924, to October, 1938, 253 blue jays have been banded at the two stations we have maintained at West Lafayette, Indiana. Most of these were banded in our yard on the western outskirts of the town. From nests in the immediate vicinity 18 young birds were banded and 27 adults were caught and banded at a substation¹ a quarter of a mile away. Traps were maintained at the substation only during the years 1931, '32, and '33, and then for only four months of each year, from the middle of March to the middle of May and the middle of September to the middle of November.

Of the 253 blue jays banded, 45 show a total of 68 returns (captures three months or more since previous captures). These 45 birds returning are 17.8%, and the 68 returns 27% of the 253 banded. Total recaptures were much higher. As the U. S. Biological Survey reports only 6.2% returns on birds of all species banded since 1920, it would seem that our blue jays have given a relatively high percentage of returns on which to base conclusions.

An examination of Table I shows that the number of birds banded in any one year varies greatly. It was highest in 1928 when 38 were banded, even though in this year there were five months, February, March, August, October, and November, in which no new birds were banded. The smallest total is for 1938 when six only were banded in five months. There is no year in which jays have been banded every month, but in 1932 only January and September were skipped. Of returns, 1929 shows the fewest with one only, and 1931 and 1932 the most with eleven and nine, respectively, while 1928 yielded five.

The distribution of total captures and returns throughout the year is interesting. Jays have been banded every month of the year, the spring and summer months predominating, with April showing the largest number, a total of 52, and February the fewest with four. Bandings for January and December each exceed those for March, October,

¹ For description of this substation see Proc. Indiana Acad. Sci. 40:369-370.

and November. Recaptures are distributed over every month of the year but are least, one each, for August and September, which were high in bandings. May and June have the most returns with April only slightly behind. February recaptures are five, one more than bandings for that month. The number of traps in operation varied through the years, but no definite relation is seen between the traps in operation and birds caught. If the year is divided into winter and summer calling April, May, June, July, August, and September summer months and January, February, November, and December winter months and not including March and October, as birds taken in these months might be hangovers from winter or summer, there are 21 birds which show returns for summer only, six for winter only, and 19 for both winter and summer. Further analysis of the returns shows that 16 birds were recaptured two or more times, ten of these both winter and summer.

A possible explanation of the large numbers banded in April and May and the many returns for April, May, and June may be that during this season, while the birds are busy with nesting duties and feeding time is limited, they find it easier to take the convenient supply of food at the traps than to forage.

Of the total returns, 13 were of birds found dead, and the rest were recaptured at one of our stations, except in a single instance when one individual, banded May 14, 1931, was caught April 7, 1932, by D. R. Burtsfield at his station on North Main St., about a mile from ours.

TABLE I.

Year	Jan.		Feb.		Mar.		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Totals		
	Bud.	Ret.	Bud.	Ret.	Bud.	Ret.	Bud.	Ret.	Bud.	Ret.	Bud.	Ret.	Bud.	Ret.	Bud.	Ret.	Bud.	Ret.	Bud.	Ret.	Bud.	Ret.	Bud.	Ret.	Bud.	Ret.	
1924																											
1925	3			1	1	1	5	2			X		X		X			5		1					15	2	
1926	2	1	1	1	2				2	1	X		X		X		1					3			11	3	
1927	1	2									1		X		9		1	8	8						19	2	
1928	1	1					2		14	1	3	9	3	1	1	X	10	1			1				38	3	
1929	2				1		8		3			1	2	7	1	5	6	2	4						31	2	
1930							2	1	1	4	3	X		1	X	X	2				1		1		10	4	
1931	1			1	3		12	4	46	7	3	13	1		1	1			1	1		2	1	1	27	11	
1932			1		1		2	3	10	2	2	3	1	1	3	1	1	4		1	1	1	2	1	1	28	9
1933							2		2			1	3	X		X			1			1		1	6	5	
1934				1			2		3		3	1	6	2	1						1		1	1	16	4	
1935		1			1		3	1			2	2	2												9	4	
1936	4		1	1	1	3		3		2			1		2	2	1		1			1		2	14	6	
1937					1	2		1	2	1	2		6	1	2						3	2	1	1	15	7	
1938	5	2	1	1	1		1		8	2					1		1		2						12	6	
Totals	19	7	2	4	5	4	10	3	0	42	10	49	52	13	18	23	11	5	27	4	10	23	2	4	26	0	11

* Station not in operation.

This station and another maintained for a time nearby were the only other stations in or near West Lafayette. None of the dead birds were found more than a mile from our banding station. Among the data on range are records of nine birds captured at both the home station and the substation a quarter of a mile away. Of 18 young birds banded from nests, only one gave a return in a later year. This bird, B-327931, was banded in the yard of a neighbor, 50 yards from our traps, May 21, 1932, recaptured in both June and July of that year and returned to our traps December 29, 1933, and again December 14, 1934.

Referring to Table II, it is seen that of the 19 birds caught both winter and summer, 12 were caught more than twice, and eight re-

TABLE II.

Bird	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
338355	15/27		18/25									11/24†
316020	18/25†	14/25										
284284	11/26				21/26					29/25†		
284362		3/26								7/25†		
284365		3/28									10/25†	
284357	8/27	10/26†										
520654						23/28		26/27†				
520655						6/28		27/27†				
520658						4/28		20/27†				
520667					17/28				6/27†			
526944					6/28†	9/29						
					30/30	5/32						
					11/31							
652113							9/29		17/28†			
A-401907				21/29†	27/31							
A-401916				39/29†								
				30/30								
A-401923					12/29†							
					29/30							
A-401954				24/31			9/29†					
A-401920					7/29†	10/30						
					8/31							
A-401958				23/31	27/30	1/33	21/29†			20/31		
				3/32								
A-401959				16/31			24/29†					
A-309436		1/31		7/30†								
A-345403				24/30†								
				9/31								
A-413644	4/31†			14/32								
374904				18/31†		9/33						
374906	27/35			20/31†	17/32							
374913				24/31†								2/31
374920					1/31†							
					25/32							
374928				7/32	14/31†							
A-379185						26/35	26/31†					
A-379200							9/32					
A-379183				1/32						23/31†	20/33	29/31†
										7/32		
B-327915		21/34	30/37	1/35	5/32†							
B-327931					21/32†							29/33
												14/34
B-362656						15/33		17/32†				
B-362872					21/37						3/32†	
B-386453										15/33†	2/34	
34-340132						19/35	25/34†					
34-340136		15/36					30/34†					
34-340158			31/35†								22/36	
34-372931	20/36†		30/37		1/38						26/36	
	1/38											
34-372933	24/36†			13/37			9/37			24/38		23/36
34-372943				4/36†				10/36				
34-372954					3/36†			11/36			20/37	
36-327226	7/38				31/37†							
36-327286	19/38	28/38					22/37†				17/37	
28-300302					4/38					9/38	10/37†	19/37

†Date of banding.

turned in four different months, one having six captures. This latter bird, A-401958, was banded July 21, 1929, at the home station, and recorded as immature. On May 27, 1930, it was taken at the substation and was recaptured at this station several times in April, 1931, beginning on the 23rd. That fall two more records were made at the same place, October 22 and November 4. The following spring it was there again on April 3 and 17, but on June 12 it was taken at the home station. It was found dead about half way between the two stations June 1, 1933. It had been caught in our traps 17 times before it died at the age of at least four years.

Other interesting returns, as shown in the table, include the following:

34-372931, banded January 20, 1936, returned December 26, 1936, March 30, 1937, January 1, 1938, and May 1, 1938.

34-372933, banded January 24, 1936, returned December 23, 1936, and April 13, 1937, and repeated July 9, 1937.

36-327286, banded July 22, 1937, returned November 17, 1937, and repeated January 19, 1938, and February 28, 1938.

B-327915, banded May 5, 1932, returned February 21, 1934, April 1, 1935, and March 30, 1937.

384362, banded October 29, 1925, repeated January 11, 1926, and returned May 21, 1926.

From the fact that several individuals have been taken in both winter and summer months, as shown in Table II, it is evident that at least a portion of the blue jay population of this region is resident throughout the year. The relatively few bandings for fall would seem to indicate that there is no great influx of migrants from the north. While the high bandings for April might be interpreted as a northern spring migration, the few captures for March and the first half of April, together with the fact that the jays frequently begin nesting by, or before, the middle of April, would indicate little such migration. Just three of our jays show records of captures both early spring and late fall only. Some of the published banding records² give a few instances of jays banded in north central states during late spring, summer, or early fall and recovered during the winter in states farther south. These are all from localities about 1.5 degrees north of our region. There are also a few records from central Indiana and northern Ohio of autumn wanderings of 15 to 40 miles. Only by the analysis of many additional banding data can the question of migration be definitely answered.

Some idea of the natural length of life of blue jays may be obtained from these records. The longest period between banding and last capture is for bird B-327915 banded May 5, 1932, as an adult. It returned three times, the last capture being March 30, 1937. This, at the very least would show the bird to be six years old. When last captured it seemed to be in perfect condition and weighed 85.3 grams against 81.3 grams at banding. Another bird, B-362875, banded November 3, 1932, was found sick and died May 21, 1937; so it must have been five years

² Lincoln, Returns from banded birds, 1923 to 1926, U. S. Dept. Agr. Tech. Bull. No. 32, 1927; Bird banding notes, Vol. 2, No. 16, 1938. (Mimeogr. by U. S. Bur. Biol. Surv.)

old or more. As there is no telling how old it was at banding, the death may have been a result of old age. Three other returns demonstrate ages of at least five years.

Results of these banding studies so far seem to justify the following conclusions for the region under discussion:

1. The blue jays seem in large part to be permanent residents. For our birds there is no positive evidence of any migration and some evidence that there is little or none.

2. Blue jays as a rule probably do not range far either for feeding or nesting, though there may be wandering during the year over an area up to a mile in diameter.

3. Individual blue jays are known to have lived at least six years and be in good condition at that age, and four are known to have lived five years or longer.

Additional Data Concerning Human Intestinal Parasite Infections in Indiana

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Introduction

The question of the status of human parasite infections in Indiana is one which yet remains to be answered satisfactorily. Only meagre information is available concerning the incidence of parasite infections in this region and their importance in reference to public health. In a former report on the subject (Headlee, 1937), the available literature was reviewed, and certain case reports of parasite infections not in the literature were mentioned. The parasites listed in that report were *Plasmodium* (causal organisms of malarial fevers), *Endamoeba gingivalis*, *Trichomonas vaginalis*, *Diphyllobothrium latum* (the fish tapeworm of man), *Enterobius vermicularis* (the pinworm or seatworm), *Filaria bancrofti*, *Trichinella spiralis* (the pork worm), and among the arthropods, *Pediculoides ventricosus* (the grain mite), and the larva of the sheep gad fly *Oestrus ovis*. For the most part this information was gained from case reports, and there were no valid data concerning the incidence of these parasites in the general population of the state. No information was available concerning the incidence of intestinal protozoa. Reasons for this lack of information were set forth, data concerning the human parasite infections of neighboring regions were cited, and the hypothetical status of human parasite infections in Indiana was presented. It was concluded that "Indiana may have a considerable incidence of human parasite infections, particularly in the southern part of the state, but definite proof of this probable condition awaits more detailed studies than have at present been made."

During the past two years an attempt has been made to gain further information concerning human parasite infections in Indiana, particularly in reference to the incidence of intestinal parasites. The additional data now available have been obtained primarily from surveys conducted at Longcliff State Hospital, Logansport, Indiana, and among students at Purdue University. Other data have been obtained from the examination of individuals not included in the two groups just mentioned.

Materials and Methods

The only accurate method of detecting and diagnosing infections of intestinal parasites is by a microscopic examination of fecal material from the individual in question, which examination will reveal the ova of worms and the cysts and trophozoites of protozoa, if present. There are certain exceptions to this rule. Only a small percentage of infections with the pinworm, *Enterobius vermicularis*, are detected by fecal

examinations, due to the fact that the female worms do not lay eggs while they are in the intestine. The gravid females migrate from the bowel and burst when they reach the exterior, and eggs are scattered in the perianal and perineal regions. To diagnose this infection, perianal scrapings should be made and examined microscopically. In still other cases, if and when the larger worms, or portions of them, are passed in the stool, they may be examined and identified. However, an individual may have a parasite infection for years before it is detected in this latter manner.

The present data were obtained by microscopic examination of fecal specimens. The specimens were collected in cardboard containers and examined within 24 hours after collection. Both unconcentrated and centrifugalized, concentrated preparations were examined from each fecal specimen. A smear was made by comminuting a portion of fecal specimen in a few drops of physiological saline solution on a 40 x 75 mm. slide. A cover glass was placed over a portion of the smear, and to the remaining portion a drop of Donaldson's iodine was added before covering. This preparation was then examined under the microscope. A portion of the stool was comminuted in tap water, strained through gauze, and centrifuged. A portion of this concentrate was used to make an iodine-stained preparation for further examination. In this manner both trophozoites and cysts of protozoa and eggs and larvae of helminths can be observed in their natural and fixed conditions.

In 1936 Kmecza (1939) examined 1,200 patients of Longcliff State Hospital, Logansport, Indiana, for intestinal parasites. The patients of the hospital were all from northern Indiana, i.e., they had established their residence in the northern part of the state at least a year previous to admission to the hospital. Therefore, the results of this survey are a good indication of the incidence of infection with various species of intestinal parasites for this locality. Of the 1,200 patients examined, 565 were males and 635 were females. Among this group of patients 622, or 51.8%, were harboring one or more species of protozoa, helminths, or both. Six hundred and eighteen patients, or 51.5%, were infected with one or more species of protozoa; 20 patients, or 1.7%, harbored helminth infections, and 14 patients, or 1.2%, were parasitized with one or more species of protozoa and one species of helminth. The species of protozoa and helminths noted and the percentage incidence of each were as follows: *Endamoeba histolytica*, 0.2; *Endamoeba coli*, 31.3; *Endolimax nana*, 37.7; *Iodamoeba bütschlii*, 3.2; *Giardia lamblia*, 1.8; *Enterobius vermicularis*, 1.6; and *Diphylllobothrium latum*, 0.1.

During the past two years, primarily during the spring of 1937, a number of students of Purdue University were examined for intestinal parasites.¹ One hundred and forty-seven of these students indicated that their residences were in Indiana, and the data obtained will add to our knowledge of the incidence of intestinal parasites in this state. Of this number, 118 were males and 29 were females, ranging in age from 17 to 36 years. Of these students, 64, or 43.6%, were infected with one or

¹ The writer wishes to acknowledge with thanks the cooperation of Dr. S. J. Miller, director of the Purdue University Student Health Service, and members of his staff.

TABLE I.—The Incidence of Human Intestinal Parasites Among Individuals of Various Indiana Population Groups.

SEX		POPULATION GROUP		LONGCLIFF STATE HOSPITAL						STUDENTS OF PURDUE UNIV.						MISCELLANEOUS						TOTAL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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more species of protozoa, and one, or 0.07%, with one species of helminth. The species of protozoa and helminth noted and the percentage incidence of each were as follows: *Endamoeba histolytica*, 3.4; *Endamoeba coli*, 17.7; *Endolimax nana*, 32.0; *Iodamoeba butschlii*, 0.07; *Giardia lamblia*, 3.4; *Chilomastix mesnili*, 0.07; and *Trichocephalus trichuris*, 0.07. Although these students had visited the Student Health Service for medical attention, only a small percentage of these were seeking relief from gastro-intestinal disturbances. In some instances the gastro-intestinal illness was proved to be due to, or enhanced by, parasite infection; in others it was not due to the presence of parasites.

Additional data may be added from the results of examinations of 13 other individuals residing in Lafayette and vicinity. These individuals sought examinations because they were desirous of knowing whether or not they were harboring infections. Thirteen persons were examined, 8 males and 5 females, ranging from 2 to 45 years of age.

Ten, or 76.9%, were infected with one or more species of protozoa, helminths, or both; 6, or 46.2%, harbored helminths, and 5, or 38.5%, had infections of protozoa. The parasites noted and percentages of incidence were as follows: *Endamoeba histolytica*, 7.7; *Endamoeba coli*, 23.1; *Endolimax nana*, 23.1; *Chilomastix mesnili*, 7.7; *Ascaris lumbricoides*, 7.7; *Enterobius vermicularis*, 30.8; and *Hymenolepis nana*, 7.7.

Combining the data from these three groups, the following percentage incidences of parasitism were noted; *Endamoeba histolytica*, 0.6; *Endamoeba coli*, 29.7; *Endolimax nana*, 36.9; *Iodamoeba Butschlii*, 2.9; *Giardia lamblia*, 2.0; *Chilomastix mesnili*, 0.15; *Ascaris lumbricoides*, 0.07; *Trichocephalus trichuris*, 0.07; *Euterobius vermicularis*, 1.7; *Hymenolepis nana*, 0.07; and *Diphyllobothrium latum*, 0.07. Of the 1,360 individuals examined 687, or 50.5%, were infected with one or more species of protozoa; 27, or 2.0%, were infected with helminths, and 16, or 1.2%, were infected with both protozoa and helminths, while 696, or 51.2%, were harboring infections of protozoa, helminths, or both.

The data for these three groups of individuals and the combined groups are presented in Table 1.

Discussion and Conclusions

The data presented in this paper give us a more complete picture of the incidence of human intestinal parasites in Indiana than has previously been available. However, more data are necessary before a complete picture can be presented. To date only a relatively small group of persons have been examined, and they were not representative of the general state population. Those individuals examined by one survey were representatives of a select group living under excellent sanitary conditions. The second group, representing university students, may be considered as a sample of the population group that has been more fortunate in regard to sanitation and general economic conditions. Therefore, a representative sampling of the population of the state has not yet been obtained, only a very few having been examined from the group representing the lower economic and social levels. Also, only a very few

children were examined, and in this group we would expect a higher incidence.

The incidence of *Endamoeba histolytica*, 0.6% for the general group is very low. Craig (1934) estimated that from 5 to 10% of the people of the United States were carriers of this parasite. The incidence of this parasite among the students, (3.4%) more nearly approaches this estimated figure.

If perianal scrapings had been examined, it is quite certain that the incidence of *Enterobius vermicularis* would have been considerably higher. The incidence of all parasites would no doubt have been higher if more than one examination of each person had been made.

The case of *Diphyllobothrium latum* infection was of interest because of an unusual clinical history, reported in detail by Headlee, Kmecza, and Cable (1939). This is the fifth case of diphyllobothriasis to be reported from Indiana.

The data presented justify the previous conclusion that "Indiana may have a considerable incidence of human parasite infections." The present data indicate that the incidence of pathogenic species is low, but, as examinations are made from a more representative part of the population, this incidence will probably increase.

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A Preliminary Survey of the Surviving Species of Caudata of Vigo County and Vicinity

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This report on the surviving species of Caudata in Vigo County and vicinity is based upon a rather extensive survey made over a period of some six years. The specimens were identified by descriptions in Pratt's *Manual of the Land and Freshwater Vertebrates of North America*. Specimens about which there was doubt of correct identity were sent to Dr. Karl P. Schmidt of the Field Museum, Chicago, for confirmation.

Some three or four thousand specimens have been collected, representing 12 species. Observations have been made at some length on the life habits of these species both in their native habitats and under controlled conditions in the laboratory.

Certain definite changes appear to have occurred in the fauna of this region since a report was made by W. S. Blatchley, 1899. Some species reported common in this area at that time now appear to be quite rare; other species seem to be increasing noticeably in numbers.

This survey should not be considered either complete or final. Further research may disclose additional facts about this group, and it is hoped that new species will be added to the list already compiled.

Necturus maculosus, Mud-puppy or Water Dog. (Fig. 1.) This comparatively large salamander is rather common in the Wabash River and occurs sparingly in some of the smaller streams of Vigo County. Its fondness for earthworms, crawfish, and minnows has earned notoriety for the species as an inveterate bait-stealer. It also feeds on insects and their larvae, mollusks, and occasionally on smaller salamanders.

Frequenting the deeper portions of the stream as it does, the Mud-puppy is seldom taken except on fish-lines. It is interesting that the species is seldom or never taken during the warmer months of the year, but it is often caught during the cool seasons of late fall and early spring. The bodies of specimens taken in the fall appear gaunt and lean, but in the spring they often appear plump and well laden with meat. This body condition may indicate a period of fast during the hot summer months followed by heavy feeding during the winter. Also it may help to explain why the Mud-puppy is so seldom taken by fishermen during the hot weather.

The largest specimen taken measured 16½ inches in length, although the average size is about 12 inches.

Ambystoma texanum, Small-mouth Salamander. (Fig. 2.) The Small-mouth Salamander abounds in the Wabash River lowlands but is seldom found elsewhere in the county. In a series of approximately two thousand specimens collected, wide color variations were noted: light



Fig. 1. *Necturus maculosus*, Mud-puppy, Water Dog.
Fig. 2. *Ambystoma texanum*, Small-mouth Salamander.
Fig. 3. *Ambystoma tigrinum*, Tiger Salamander.
Fig. 4. *Ambystoma maculatum*, Spotted Salamander.

silvery gray, greenish slate, brownish, lead colored, and almost jet black in some instances. Some were mottled; others were immaculate. An albino was collected April 17, 1937.

The average length of adults appears to be about five or six inches; but one giant specimen, which was taken from a cellar in Terre Haute, measured nine and one-half inches. It probably reached this unusual size because of exclusion of certain natural enemies, notably the garter snakes.

When attacked, this salamander has a faculty, which it holds in common with many other species, of exuding an irritating, distasteful secretion from pores in the skin. The garter snakes and water snakes do not seem to be the least bit offended by this material, but a Copperhead in the laboratories showed signs of distress after biting one of these specimens and refused to engulf it until it had been washed free of the odious secretion.

Ambystoma tigrinum, Tiger Salamander. (Fig. 3.) The Tiger Salamander is the species most often seen in Terre Haute, probably because of its predilection for wells, cellars, open vaults, and other such places in the city. It also frequents the river lowlands but is much less common there than the Small-mouth Salamander. The coloration consists of irregularly arranged yellowish or tan spots superimposed upon a dark brown or blackish body. Some specimens collected measure as much as nine inches in length. The Tiger Salamander feeds voraciously on earthworms, insects, and mollusks, as well as frogs and smaller salamanders.

Ambystoma maculatum, Spotted Salamander. (Fig. 4.) The Spotted Salamander seems to be rare in this area; only two specimens have been collected to date. To the contrary, this species was formerly reported rather common in Vigo County by W. S. Blatchley in 1899.

The Spotted Salamander may be easily distinguished from the Tiger Salamander by the two dorsal longitudinal rows of bright canary yellow spots and the uniform bluish-slate colored sides.

Ambystoma opacum, Marbled Salamander. (Fig. 5.) This strikingly marked salamander is rare in Vigo County and vicinity. Only two specimens have been collected during the survey. One was taken from near North Terre Haute during 1935, and the other specimen was found in a damp woodland near Youngstown in September, 1937. The Marbled Salamander can be distinguished unmistakably from any other species in our area by means of color alone. The body color is jet black with about 14 transverse silvery white bands on the back. The species is small and seldom exceeds four and one-half inches.

Plethodon glutinosus, Slimy Salamander. (Fig. 6.) The Slimy Salamander is common in moist woodlands throughout Vigo County but is not found in the annually flooded river bottoms. It seems to be almost entirely insectivorous and feeds readily on termites, caterpillars, and beetles. Coloration consists of a shiny, anthracite-black body, more or less sprinkled with small white dots.

This is probably the largest of the Plethodontidae in Indiana. Specimens have been found which measured seven inches in length.



Fig. 5. *Ambystoma opacum*, Marbled Salamander.
 Fig. 6. *Plethodon glutinosus*, Slimy Salamander.
 Fig. 7. *Eurycea longicauda*, Long-tailed Salamander.
 Fig. 8. *Eurycea lucifuga*, Cave Salamander.

Plethodon cinereus, Red-back Salamander, Gray Salamander. Both the red-backed and gray phases occur in Vigo County. The largest specimen examined was from North Terre Haute. It measured five inches in length and one-third of an inch in diameter. The food of this species, so far as it can be determined, consists of small insects.

Plethodon dorsalis. Although not yet recorded, it is very probable that this species does occur in Vigo County, since specimens have been collected from the neighboring counties, Parke, Clay, Owen, and Brown.

It may be distinguished from the Red-back Salamander by the dentate borders of the dorsal stripe, sometimes resembling a chain of rhombs. It feeds on small insects.

Eurycea bislineata bislineata, Two-lined Salamander. The Two-lined Salamander is common in most small woodland streams and spring overflows. Coloration consists of a yellowish tan body with two dorsal longitudinal stripes. This species seldom exceeds four inches in length and is insectivorous in feeding habits.

Eurycea longicauda, Long-tailed Salamander. (Fig. 7.) The Long-tailed Salamander is apparently rare in Vigo County, since only three specimens have been taken during the survey. One of these was a young specimen, which was taken in the river lowlands where it doubtless had been carried by the spring floods.

The Long-tailed Salamander may be recognized easily by the yellowish body color, definitely mottled with black, and by the vertical bars of black on the tail. It seems to prefer a limestone or shale habitat and exhibits a fondness for insects and other small aquatic life.

Eurycea lucifuga, Cave Salamander. (Fig. 8.) Although not yet recorded, future collecting may possibly show the Cave Salamander to be a resident of Vigo County. Many specimens have been collected in Owen County at McCormick's Creek State Park. The Cave Salamander seems to prefer the cool, dark, damp caves and sinkholes so frequently found in limestone formations; other species of the same genus are seldom found in these dismal locations.

The orange-red body, sprinkled with black dots, makes this salamander one of the prettiest of Indiana forms.

Siren intermedia, Mud-eel. Two specimens of this odd salamander were collected in the spring of 1938. One was found in a flooded field at North Terre Haute, and the other specimen was taken on a fish-line in the Greenfield Bayou in southern Vigo County.

The Mud-eel is distinct from all other salamanders in Indiana in that it possesses only the anterior pair of legs. The eel-like body and external gills are also strong points for identification. The food consists of earthworms, crustaceans, and mollusks.

Although *Cryptobranchus alleganiensis*, the Hellbender, is reported by Glenn Cowgill, Vigo County game warden, to be rather common in the Wabash River south of Terre Haute, as yet no specimens have been added to our collection.

Further investigation, it is hoped, may also disclose *Triturus viridescens*, the Newt, *Ambystoma jeffersonianum*, and *Hemidactylum scutatum*, all of which were reported by W. S. Blatchley in 1899.

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Notes on Indiana Fresh Water Sponges

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When a zoology teacher mentions sponges his students at once think of the ordinary commercial sponges, for the excellent reason that these are the only kind most of them have ever seen or heard of; they are quite unaware that sponges may be found in streams and fresh-water lakes in many places. Apparently but few have been interested in these simple animals, and this, added to the fact that they are of no economic importance, has tended to keep them in obscurity.

This is a preliminary report on some work that has been done in investigating the sponges in some of the lakes and streams of two counties thus far—Kosciusko and Wabash. In this area sponges are to be found most numerous in the lakes and their immediate outlets. Only a very few have been found in streams other than lake outlets. As an example, Eel River was explored rather thoroughly for about a mile and in that distance but two small specimens were found, the largest being about a quarter of an inch in diameter. In every case, with the exceptions noted above, when smaller streams were investigated, not a single specimen was found. The reason for this is evidently the amount of sediment carried by these streams; for there are records from streams in other parts of the state. Since sponges depend for their food and oxygen on water that must pass through rather minute pores, any sediment will manifestly prove a serious handicap to them.

But some of the lakes tell a different story. A few seem to be without sponges, as diligent search has failed to disclose any; but in others they are more or less abundant. In the author's experience, a good way to determine their presence in a given lake is to examine the outlet of the lake. Here one is very likely to discover many specimens of the kinds to be found in the lake itself, on submerged sticks, on stones or gravelly bottoms, on roots that project into the water, and sometimes on various water weeds. It is interesting to note that though many specimens may be found in such a location, farther down the stream the matter of sediment seems again to become the dominant factor, and sponges are not to be found. Because of the sedimentation that occurs in the lake, the water there and in its outlet furnishes an environment that is usually very satisfactory for sponges. If they are found in a given lake they are often abundant in some parts of it, while in others that look as well adapted they may be entirely absent. In the lakes examined, most specimens were found on rushes growing in shallower water and very rarely on other submerged objects, evidently because the latter are rarely free from algae or sediment of some sort. For some reason they seem to prefer the cylindrical stems to triangular ones and at times they are found almost exclusively on rushes that have been cut or broken off at about the water level. It is possible that the action of wind on the

rushes may explain this behavior. Potts suggests that they will be found rarely or not at all in water containing considerable amounts of lime; but many found on rushes show the presence of lime deposits in and about them in quantities sufficient to be quite noticeable, thus demonstrating that they are able to exist in the presence of this substance.

Pretty generally the specimens found are of the "encrusting" type. The only exceptions are those found growing on roots or matted weeds. Because in growing they follow the numerous branches of these, they are found in a few cases to be somewhat "massive" but rarely of the size of a finger. They vary considerably in surface texture and somewhat in appearance, but those found are rarely branched. Occasionally they have slight elevations, but these would scarcely be called branches. Most sponges are some shade of tan, though, if they have grown where they are exposed to direct sunlight, they are usually green shading to tan or whitish as they reach the more shaded part of their support. They have a distinctive odor which, once it is recognized, is sometimes of use in distinguishing doubtful specimens from certain algal growths at time of collecting. This, coupled with the use of a small pocket lens rarely leaves one in doubt as to the identity of a given specimen.

Potts reports observing sponges throughout the winter and in the South they seem to be regularly perennial, but none have been found in the area explored. They have been found on rushes by the middle of June, but by mid-November they usually have completely disappeared except for gemmules, sometimes interspersed with a few spicules. The gemmules seem to adhere to the base on which they grew and start the sponge anew the following summer. Most species do not form gemmules until October 1 or later, though some have been found as early as the fore part of August. In one or two species, notably *Spongilla aspinosa*, it is difficult to find gemmules at any time, but it is evident that they must form or that these are perennial.

In Vol. XIV of the Illinois Natural History Survey, Smith names seven species as being reported from this state, viz: *Spongilla fragilis*, *Ephydatia crateriformis*, *Heteromeyenia argyrosperma*, *H. repens*, *H. ryderi*, *Carterius latitenta* and *C. tubisperma*. In addition he states that *Ephydatia fluviatilis* or *E. mülleri* should be included, though he is unable to determine which from the reports, as these two are often confused. Not all of these have been found in the area examined but five species have been identified, three of which are to be found in his list. *Spongilla fragilis* and *Carterius tubisperma* are numerous as is also *Ephydatia mülleri*; and if one follows some authorities and divides this last into two species—*mülleri* and *japonica*—both are to be found. Two species not listed by Smith are to be found here—*Spongilla aspinosa* and *S. lacustris*, though neither is as common as the other three. It is hoped that wider search will reveal a number of other species.

Indiana Mastodons*

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There are records of mastodons from 46 of Indiana's 92 counties. Most of the records are based on rather fragmentary remains and are in scattered collections, but several of them are based on practically complete skeletons. With two exceptions all of these skeletons are deposited or exhibited in museums outside of Indiana, which has no state museum of its own.

The portion of Indiana where mastodons are found most abundantly is in the north and east. Perhaps the finest skeleton known was found in DeKalb County and is on exhibit in the Carnegie Museum in Pittsburgh. Another excellent completely mounted specimen was found in Pulaski County and is now on exhibit in the United States National

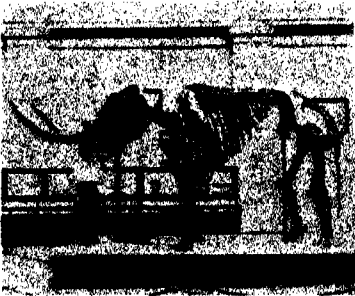


Fig. 1. Pulaski County; United States National Museum.



Fig. 2. Miami County; Milwaukee Public Museum.

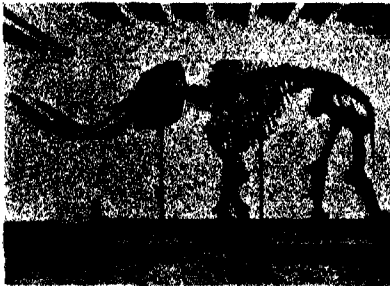


Fig. 3. DeKalb County; Colorado Museum of Natural History.



Fig. 4. DeKalb County; Carnegie Museum, Pittsburgh.

* Read in the general session of the Academy.

Museum. One of the early mastodon skeletons found in Indiana came from the vicinity of Denver, Miami County, and is exhibited in the Public Museum of Milwaukee. The last good specimen of mastodon was found near Garrett, DeKalb County, and is exhibited in the Colorado Museum of Natural History. A fairly complete skeleton from Marshall County, as yet unmounted, is in the collection of the American Museum of Natural History. Another fairly complete specimen, as yet unmounted, from Noble County is in the Buffalo Museum of Science, New York.

Two good unmounted specimens are in Indiana collections, an immature one at Taylor University from Grant County, and another at Earlham College from Wayne County. The Earlham specimen, which was dismounted at the time of their fire, is now being reassembled.

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MEMBERSHIP LISTS—The complete list of members of the Academy was last published in Vol. 46 (1937) of the Proceedings, and supplementary lists appear in following volumes. For the effect that it may have in stimulating activity, a complete list of Junior Academies is published each year as a part of the report on the Junior Academy.

CONSTITUTION AND BY-LAWS—The constitution and by-laws of the Academy were last published in Vol. 44 (1935). A codified list of duties of officers and chairmen of committees was published in Vol. 48 (1939).

EDITORIAL CODE—A general editorial code was published in Vol. 44 (1935). Additional directions for the preparation of manuscripts have been printed in leaflet form, and copies of this may be secured from the Editor.

Membership lists and copies of the constitution and by-laws may be secured from the Secretary.

¹Abstract.

OFFICERS AND ELECTED COMMITTEES FOR 1939

OFFICERS

President, T. G. YUNCKER, DePauw University.
Vice-President, L. A. TEST, Purdue University.
Secretary, WILLIAM P. ALLYN, Indiana State Teachers College.
Treasurer, W. P. MORGAN, Indiana Central College.
Editor, PAUL WEATHERWAX, Indiana University.
Press Secretary, WILL E. EDINGTON, DePauw University.
Trustees Academy Foundation: JOHN S. WRIGHT, Eli Lilly and Company (term expires 1940); F. B. WADE, Shortridge High School (term expires 1939).
Committee for Bonding Trustees: H. L. BRUNER, Butler University; W. A. COGSHALL, Indiana University.
Research Grant Committee: A. L. FOLEY, Chairman, Indiana University (term expires 1941); E. G. MAHIN, University of Notre Dame (term expires 1942); H. E. ENDERS, Purdue University (term expires 1940); RAY C. FRIESNER, Butler University (term expires 1939); JOHN S. WRIGHT, Indianapolis (term expires 1943); T. G. YUNCKER, DePauw University (ex officio); WILLIAM P. ALLYN, Indiana State Teachers College (ex officio).

DIVISIONAL CHAIRMEN

Archeology, PAUL WEER, 1808 N. Delaware Street, Indianapolis.
Bacteriology, W. A. JAMIESON, Eli Lilly and Company.
Botany, WINONA WELCH, DePauw University.
Chemistry, HERMAN T. BRISCOE, Indiana University.
Geology and Geography, THOMAS M. BUSHNELL, Purdue University.
Mathematics, P. D. EDWARDS, Ball State Teachers College.
Physics, R. B. ABBOTT, Purdue University.
Psychology, AMMON SWOPE, Purdue University.
Zoology, C. P. HICKMAN, DePauw University.

EXECUTIVE COMMITTEE

(Past Presidents, Officers, Divisional Chairmen, and Chairmen of Standing Committees)

Abbott, R. B.; Allyn, W. P.; Andrews, F. M.; Arthur, J. C.; Behrens, C. A.; Blanchard, W. M.; Blatchley, W. S.; Briscoe, H. T.; Bruner, H. L.; Burrage, S.; Bushnell, T. M.; Christy, O. B.; Cogshall, W. A.; Coulter, Stanley; Cumings, E. R.; Davis, J. J.; Deam, C. C.; Edington, W. E.; Edwards, P. D.; Enders, H. E.; Foley, A. L.; Friesner, R. C.; Gingery, W. G.; Hessler, R.; Hickman, C. P.; Jamieson, W. A.; Swope, Ammon; Lilly, Eli; Lyon, M. W., Jr.; Mackell, J. F.; Mahin, E. G.; Martin, E. S.; Moenkhaus, W. J.; Montgomery, B. E.; Morgan, W. P.; Mottier, D. M.; Naylor, J. P.; Noyes, H. A.; Payne, F.; Ramsey, R. R.; Rettger, L. J.; Test, L. A.; Wade, F. B.; Wallace, F. N.; Weatherwax, Paul; Weer, Paul; Welch, Winona; Wright, J. S.; Yuncker, T. G.

STANDING COMMITTEES

(Appointed by the President, chairman of each committee named first).

Archeological Survey: Eli Lilly, Glenn A. Black, R. E. Esarey, E. Y. Guernsey, C. F. Voegelin, C. A. Malott.

Auditing: E. S. Martin, William Johnson.

Biological Survey: B. E. Montgomery, Winona Welch, C. M. Palmer, S. R. Esten, M. W. Lyon, Jr., B. H. Smith.

Library: Walter G. Gingery, Ray C. Friesner, Nellie M. Coats.

Membership: O. B. Christy, A. R. Bechtel, Floyd E. Beghtel, C. A. Deppe, F. R. Elliott, A. R. Eikenberry, R. E. Girton, D. L. Harmon, G. D. Klopp, F. A. Loew, M. S. Markle, R. E. Martin, H. G. Nester, Theodore Just, H. M. Powell, W. D. Thornbury, W. LeRoy Perkins, W. J. Tinkle, S. W. Witmer, J. L. Riebsomer.

Program: J. F. Mackell, D. L. Harmon, B. H. Howlett, B. H. Smith, Bessie Noyes, R. W. Karpinski, and Divisional Chairmen.

Publication of Proceedings: Paul Weatherwax, J. J. Davis, C. A. Behrens, F. B. Wade, M. E. Hufford, E. S. Conklin.

Relation of Academy to State: F. N. Wallace, J. S. Wright, Stanley Coulter, E. Y. Guernsey, Harry J. Reed, D. A. Rothrock.

Representative on A.A.A.S. Council: Howard E. Enders.

Nominations: Ray Friesner, C. A. Behrens, M. W. Lyon, Jr.

Junior Academy of Science: H. E. Enders, F. B. Wade, O. B. Christy, P. D. Wilkinson, F. J. Breeze, C. F. Cox, M. M. Williams.

MINUTES OF THE COUNCIL MEETING

GREENCASTLE, INDIANA, MARCH 18, 1939

The meeting of the Executive Council, held in the Administration Building at DePauw University, was called to order by President Yuncker at 2:30, with the following Academy members present: R. B. Abbott, W. P. Allyn, H. T. Briscoe, T. M. Bushnell, O. B. Christy, P. D. Edwards, R. C. Friesner, C. P. Hickman, J. F. Mackell, E. S. Martin, W. P. Morgan, L. A. Test, F. N. Wallace, Paul Weatherwax, Winona Welch, T. G. Yuncker, W. A. Jamieson, Paul Weer, and A. Swope.

Officers and committees reported as follows:

Auditing Committee. Mr. Martin stated that the books of the Treasurer had been audited and found correct in every respect, but the books of the trustees of the Academy Foundation had not been audited.

Treasurer. Mr. Morgan gave a tentative report. It was stated that, inasmuch as the fiscal year for the Academy ends December 31, no complete report was available. He also stated that a complete report for 1938, approved by the Auditing Committee, would appear in Volume 48 of the Proceedings.

Editor. Dr. Weatherwax stated that type was all set for the 1939 Proceedings, about six weeks ahead of the previous year, and the Proceedings would be out by May. Arrangements for payment should be made by June 20. It was also emphasized that, in order to facilitate the work of the Editor, manuscripts must be in within ten days after the fall meeting.

Research Committee. Dr. Foley was absent but indicated by mail that no applications for the Academy Research Fund had been made. It was suggested that some means be provided to familiarize the members of the Academy with amount and purpose of funds available and with the time and methods for making application for the same.

Program Committee. New Harmony, Indiana, May 12 and 13, were recommended as the place and time for the spring meeting of the Academy. This recommendation met with the unanimous approval of the Council.

Biological Survey. Miss Welch reported that additional collections were being made and that Deam's *Flora* was now in press.

Membership. Dr. O. B. Christy stated that the committee had set about to interest good material in membership in the Academy. The question of how much encouragement should be given high school students to become affiliated with the Academy was discussed.

Relation of Academy to State. F. N. Wallace stated that a cut of 10% had reduced the state appropriation to \$1,350 per year for the next two years. The Publication and Library Committees were instructed to apportion this fund for publication of the Proceedings and binding exchanges as in their judgment seemed best.

New Business. Dr. Weatherwax asked if the Academy wished to sponsor a meeting of the Botanical Society of America. It was decided

that a committee of four be appointed to invite the Society to meet in Indiana in 1939. President Yuncker appointed Paul Weatherwax, Ray C. Friesner, Ralph Kriebel, and F. A. Loew.

A Nomination Committee consisting of Ray C. Friesner, chairman, C. A. Behrens, and Marcus W. Lyon, Jr., was appointed by President Yuncker.

The Council adjourned at 4:45.

MINUTES OF THE SPRING MEETING

NEW HARMONY, INDIANA, MAY 12 AND 13, 1939

The Indiana Academy of Science convened for its annual spring meeting in New Harmony. At the regular meeting in the Murphy Auditorium on the evening of May 12, the Academy was very cordially welcomed to New Harmony and asked to partake generously of the hospitality of the city by Miss Mary E. Fauntleroy, one of the surviving pioneers who exemplifies that which New Harmony means to the history of Indiana.

During the program that followed, Miss Eva Long, native of New Harmony, read an interesting paper on "Harmonie and New Harmony." Ross Lockridge, of Bloomington, discussed the "Scientific Background of New Harmony," and S. G. Elder, of the Sun Oil Company, discussed "Recent Contributions to the Geology of Southwestern Indiana and Adjacent Parts of Illinois and Kentucky."

A short business session followed.

Dr. Foley reported that the Research Committee had granted \$150 to H. T. Briscoe, of Indiana University, for research studies on measurements of di-electric coefficients and di-poles of organic compounds.

The membership committee submitted applications from ten prospective members, all of whom were elected.

Dr. Friesner of the Library Committee stated that, contrary to a previous report of a cut of 10% in the appropriation for the Academy, the State Legislature had again granted \$1,500 per year for the next two years.

Dr. Weatherwax stated that the Proceedings would be off the press by the end of May. It was decided to distribute the Proceedings as soon as completed in order to avoid confusion resulting from changes in addresses during the summer.

It was also stated that an invitation, extended to the Botanical Society of America to meet in Indiana this year, had been declined because of other arrangements. It was decided to extend invitation for future date.

President Yuncker read a letter of resignation tendered by Dr. Knight, Purdue, Chairman of the Division of Psychology for 1939. The Academy ruled that the president be given power to fill such vacancies incurred between annual fall meetings. Dr. Ammon Swope of Purdue was appointed to fill this vacancy.

Dr. Test expressed the deepest appreciation of the Academy for the fine hospitality extended by the citizens of New Harmony, and a vote of thanks was extended the Tri Kappa Sorority for its assistance.

A series of tours was conducted Saturday morning. One tour was conducted under the supervision of the citizens to the interesting sites about New Harmony, reminders of the Rappite and Owen communities; another was made to observe oil developments in the vicinity; and a third was taken to Hovey's Lake, recently taken over by the State Department of Conservation.

PROGRAM OF THE WINTER MEETING

INDIANA STATE TEACHERS COLLEGE

NOVEMBER 9-11, 1939

THURSDAY, NOVEMBER 9

7:00-9:00 p. m. Registration.

7:30 p. m. Meeting of the Executive Committee.

FRIDAY, NOVEMBER 10

8:00 a. m.-12:00. Registration.

9:00 a. m. General Session.

Address of Welcome—President R. N. Tirey, Indiana State Teachers College.

Response—Vice-President L. A. Test.

Selections—College A Capella Choir, Indiana State Teachers College.

Business Session.

Necrology—Will E. Edington, DePauw University.

For Memorials, see pp.

"The Days of a Naturalist"—W. S. Blatchley, Indianapolis.

"The Use of Kodachrome Slides in Teaching Limnology"—M. R. Garner, Earlham College.

1:00 p. m. Sectional meetings. See: Archeology, p. 16; bacteriology, p. 41; botany, p. 62; chemistry, p. 94; geology and geography, p. 118; mathematics, p. 175; physics, p. 179; psychology, p. 196; zoology, p. 199.

6:00 p. m. Annual Dinner.

Business Session.

8:00 p. m. "America the Beautiful"—Forum Fraternity, Indiana State Teachers College.

Selections—Rose Polytechnic Institute Glee Club.

President's Address—"Parasitism as a Way of Life," T. G. Yuncker, DePauw University (read by Dr. Winona Welch).

SATURDAY, NOVEMBER 11

9:00 a.m. Taxonomists' Meeting. Chairman, Fred A. Loew, Huntington College. See p. xxiii.

9:00 a. m. Entomologists' Meeting. Chairman, P. T. Ulman. See p. xxiii.

9:00 a. m. Junior Academy of Science, Business Meeting and Exhibits.

1:00 p. m. Program of Junior Academy. See p. xviii.

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

NOVEMBER 9, 1939

The Executive Committee of the Indiana Academy of Science met in the Student Lounge of the Indiana State Teachers College, November 9. The meeting was called to order at 8:00 p. m. by Vice-President L. A. Test. The minutes of the Council meeting at Greencastle, March 18, and of the spring meeting at New Harmony, March 12 and 13, were read and approved. Officers and committees reported as follows:

Academy Trustee. Mr. John S. Wright gave a detailed report of the Foundation funds of the Academy for 1938-1939 as follows:

Receipts

Balance from previous year.....	\$1,112.58
Total receipts.....	446.96
Total	\$1,559.54

Expenditures

Withdrawal to purchase \$1,000--3¼% Federal Farm Mortgage Corp. bond of '44-'64.....	\$1,093.34
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Balance in Indiana National Bank Savings Acct.....	\$ 466.20
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Assets in the Fund as of Nov. 1, 1939

United States Treasury Bonds.....	\$4,700.00
Consolidated Federal Farm Loan & Mort. Bonds.....	2,500.00
Muncie Masonic Temple Assn. Preferred Stock.....	200.00
Standard Oil Company of Indiana.....	150.00
Savings Bank Balance.....	466.20

Total Assets at par.....	\$8,016.20
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The report was accepted. It was added that the Foundation earnings were now approaching \$250.00 annually and that some of these earnings might well be used for research grants to stimulate and aid research among members of the Academy.

Auditing Committee. A written report, submitted by the Auditing Committee, stated that the books of the Treasurer had been audited and found correct in every respect and in excellent condition. The books of the trustees of the Academy Foundation had not yet been audited.

Biological Survey. No formal report was rendered. Dr. Lyon of that committee expressed regret that no more activity was shown by the Biological Survey Committee. Dr. Welch of the same committee stated that her work with mosses and liverworts was being continued and that a third paper was ready for publication. It was voted that the Biological Survey Committee be asked to assemble reports of all studies completed.

Bonding Committee. The recommendation that the bond of each trustee of the Academy Foundation be increased to \$5,000, because of the increased value of the assets of the Foundation, was approved. It

was also suggested that the chairman of the committee investigate the possibility of securing these bonds at a lower rate than that now in effect.

Editor. The Editor submitted the following report:

Volume 48 of the Proceedings was delivered to the State Library near the end of June. This earlier date of completion was secured through a ruling of the State Board that all work paid for out of the budget of any one fiscal year be completed before the end of that year. The following statistics indicate the cost of publication:

Number of copies printed.....	1600
Number of pages printed.....	283
Cost of engraving, printing and binding.....	\$1,434.22
Cost of reprints furnished gratis.....	53.15
Cost of editorial assistance.....	209.00
Editor's expenses for postage, envelopes, mimeographing, etc.....	30.90

Total cost of publication.....\$1,727.27

The net cost per printed page is considerably higher than in previous years. The difference, which is wholly in the cost of composition, is attributed to the greater condensation of material on the pages and to the unusually large amount of tabular material and other difficult composition.

The policy adopted two years ago, of making the Proceedings a complete account of the activities of the Academy for the year, has been continued, and Volume 48 contains practically all the papers presented, or abstracts of those not published in full, as well as accounts of other activities sponsored by the sections.

The provision for paying for editorial assistance in the past two years has been very satisfactory. It has reduced the Editor's work to a minimum and made possible a better publication. Probably no other expenditure made by the Academy yields any better return.

The last complete list of members was published in Volume 46 (for 1936). It would seem appropriate to publish the list again in Volume 50 (for 1940) and to expand the data about each member to indicate his interests or his institutional connections. If this is done, the information must be compiled during the coming year.

A number of recommendations made by the Editor were discussed. The appropriation of \$200 for editorial assistance was continued, and the apportionment of funds for publishing the Proceedings and binding exchanges was referred to a committee consisting of the Treasurer, the Editor, and the chairmen of the Library Committee and the Committee on Relation of the Academy to the State.

Library Committee. A detailed report of the work of the Committee was read. Letters sent to 52 scientific societies and institutions requesting exchanges resulted in the addition of about 40 new titles, several of which are represented by long files. Complete files of some could be secured if complete files of the Proceedings were available for exchange; but volumes for 1892, 1911, 1913, 1916, 1917, 1920-1929, and 1932 are no longer available. The need for continued attention to the binding of exchange material was pointed out. Taking advantage of the low rates offered by the prison bindery, the Committee has been able to have 439 volumes bound during the year. Some comment was made on the probable effect of the European wars on the publishing activities and exchange facilities of scientific institutions in the countries involved.

Membership Committee. It was reported that ten new members had been elected at the spring meeting and nineteen additional applications had been received. It was suggested that a careful survey be made of the rapid changing personnel of our universities and colleges

for valuable material that was apparently being overlooked, a survey both for the benefit of the Academy and the prospective members.

Press Secretary. Press Secretary Edington reported that reports on the activities of the Academy had been sent to the papers of the state as occasion demanded. Through cooperation with the director of publicity at Purdue University it had been possible to secure some idea of the publicity received through the papers over the state.

Relations of the Academy to the State. In the absence of the chairman, Mr. John S. Wright informed the Academy that the usual appropriation of \$1,500.00 by the State for the Academy was available.

Research Committee. The Committee announced the following awards, contingent upon the availability of the necessary funds: J. F. Mackell, Indiana State Teachers College, \$50.00; W. H. Headlee, Purdue University, \$100.00; and S. S. Visser, Indiana University, \$25.00.

Various questions of method and policy in connection with the awarding of research grants were discussed, and the further administration of the available funds was left in the hands of the Research Committee.

Treasurer. The Treasurer gave a financial report for the Academy as of January 1 to October 31, 1939.

His final report, approved by the Auditing Committee at the end of the fiscal year, 1939, was as follows:

Receipts	
Balance on hand January 1, 1939.....	\$198.43
Dues and initiation fees.....	882.00
A.A.A.S. Refund for Research.....	150.00
Sale of Proceedings.....	6.25
Author's Reprints Vol. No. 47.....	88.78
Author's Reprints Vol. No. 48.....	132.22
Gift from a member.....	250.00
	\$1,707.69
Disbursements	
1--Program Committee.....	\$180.25
2--Editor (All items of expense).....	211.35
3--Expenses of Secretary.....	55.33
4--Expenses of Treasurer.....	46.00
5--Mailing Proceedings.....	82.83
6--Stationery.....	39.05
7--Indianapolis Engraving Co.....	121.03
8--Wm. B. Burford Printing Co.....	563.23
9--Junior Academy Bulletins.....	20.00
10--Safety Deposit Box and Bond.....	30.50
11--Research Grant (Dr. Briscoe).....	150.00
12--Postage refund to officers.....	2.91
13--Returned check.....	1.00
14--Bank service charge.....	1.25
	\$1,504.73
Bank Balance.....	202.96
	\$1,707.69

The donor of the \$250 listed as the last item in the receipts gave permission to include this temporarily in the general fund, with the understanding that it later be transferred to the Academy Foundation.

Item No. 1 in expenditures includes a bill for \$41.96 incurred by the committee for 1938 and not submitted for payment until 1939.

Junior Academy of Science. A written report, submitted by the Chairman and read by the Secretary, included the following points:

The Junior Academy has maintained the standard of performance of recent years. There are at present 29 clubs in good standing, with a total membership in excess of 1,000; four new clubs are recommended this year, and others are being formed. A program of merit is arranged for this year, and members of the Academy are urged to attend and to encourage the work of the Junior Academy in all ways.

The American Association for the Advancement of Science has recognized the Junior Academy movement by arranging for honorary membership in the Association for one boy and one girl from each state, these to be selected from the membership of the Junior Academies of Science.

The Executive Committee of the Academy continued the appropriation of \$20.00 per year for the support of the publication of the Science Club Service. It also voted to endorse the selection of honorary members in the A.A.A.S. to be made by the Junior Academy.

Relation of Academy to A.A.A.S. A written report was read by the Secretary in the absence of the Chairman, calling attention to the participation of the Indiana Academy representative in the meeting of the A.A.A.S. at Richmond last winter. Further attention was directed to the interest taken by the A.A.A.S. in the Junior Academies, with special reference to the honorary membership with its awards offered to stimulate Junior Academy activities. The report was accepted.

Committee on Nominations. The following named persons were recommended for election as Fellows of the Academy: P. D. Edwards, Ball State Teachers College; W. A. Jamieson, Eli Lilly and Company; Fred A. Loew, Huntington College; C. P. Hickman, DePauw University; and George Hennion, University of Notre Dame.

New Business. The proposed selection of papers to receive honorable mention was discussed at some length. In view of the difficulty involved in making satisfactory selections in the time permitted, it was voted that action be postponed indefinitely.

On motion of its Chairman, the Committee on Archeological Survey was discontinued since its work is being done adequately by the division of Archeology.

The proposed publication of a union list of serial publications in Indiana libraries was brought to the attention of the Committee and discussed. The merits of the plan were recognized, but the Committee voted not to lend the movement financial support at this time.

The Committee declined to nominate individuals to compete for awards as outlined by the National Manufacturers' Association.

The question of the disposal of the library of the late Dr. Amos W. Butler was brought to the attention of the Committee. The advisability of the Academy's attempting to acquire this library and incorporate it in the collection now housed in the State Library was discussed at some length, but it was decided that the undertaking would not be practicable within the time limits proposed. High tribute was paid Dr. Butler for the part which he played in science in Indiana, and the hope was expressed that the library might in some way be made a living memorial of his work.

The meeting adjourned at 10:15 p. m.

MINUTES OF THE GENERAL SESSION

FRIDAY, NOVEMBER 10, 1939

An address welcoming the Academy to the State Teachers College was given by President R. N. Tirey, followed by a response for the Academy by Vice-President L. A. Test. The College A Capella choir, under the direction of L. M. Tilson, rendered several beautiful selections in a short recital.

In a short business session the minutes of the Executive Committee meeting were read by the Secretary and approved.

Will E. Edington presented the necrology of the Academy and spoke briefly of the members lost by death during the year. Dr. W. S. Blatchley read a paper on "The Days of a Naturalist," in which he recounted his wide variety of experiences as a geologist, botanist, and zoologist.

Following the annual dinner, the Committee on Nominations presented the names of 63 applicants for membership.

The Committee also offered the following nominations for officers of the Academy for 1940: *President*, Frank Wallace, Department of Conservation; *Vice-President*, S. S. Visher, Indiana University; *Secretary*, W. P. Allyn, Indiana State Teachers College; *Treasurer*, W. P. Morgan, Indiana Central College; *Editor*, Paul Weatherwax, Indiana University; *Press Secretary*, W. E. Edington, DePauw University.

The following were nominated for election as Fellows of the Academy: P. D. Edwards, Ball State Teachers College; W. A. Jamieson, Eli Lilly and Company; Fred Loew, Huntington College; C. P. Hickman, DePauw University; George Hennion, University of Notre Dame.

The Secretary was instructed to cast the ballot of the Academy for the unanimous election of all these nominees.

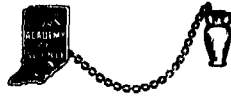
Announcement was made that the following divisional chairmen had been elected in the sectional meetings: *Archeology*, Paul Weer, Indiana Historical Society; *Bacteriology*, Dona Gaylor Graam, Terre Haute; *Botany*, Ralph Kriebel, Soil Conservation Service; *Chemistry*, Karl Means, Butler University; *Geology and Geography*, William D. Thornbury, Indiana University; *Mathematics*, Cora Hennel, Indiana University; *Physics*, J. F. Mackell, Indiana State Teachers College; *Psychology*, R. A. Acher, Indiana State Teachers College; *Zoology*, W. A. Hiestand, Purdue University.

The invitation of the Ball State Teachers College was accepted and Muncie selected as the place of the fall meeting of 1940.

The report of the Resolutions Committee, recommending an expression of gratitude and appreciation for the hospitality of the Indiana State Teachers College and the work of all who helped to make the meeting a success, was approved by the Academy.

The adjournment of the business meeting was followed by the President's address.

(Signed) W. P. ALLYN, *Secretary*.



INDIANA JUNIOR ACADEMY OF SCIENCE

Officers for 1939:

President: ELOISE CROSBY, North Side High School, Fort Wayne.

Vice-President: DONALD FRIER, West Lafayette High School.

Secretary: JAMES BELTZ, Elmhurst High School, Fort Wayne.

Members of Council: F. J. Breeze, (1935-1940); Anna Inskeep, (1936-1941); Lola Lemon, (1937-1942); J. H. Otto, (1938-1943); A. B. Krom, (1939-1944).

PROGRAM OF NINTH ANNUAL MEETING

November 9, 1939

10:00—General Session. Eloise Crosby, North Side High School, Fort Wayne, president (Donald Frier, vice-president, West Lafayette, presiding).

10:30—"Indiana Fauna," Dr. William P. Allyn, Indiana State Teachers College.

"Interesting Facts About Animals," Jack Reeves, Lew Wallace High School, Gary.

11:30—Election of Officers.

1:00—"What Makes a Live Club?" M. M. Williams, Sponsor of Bloomington Science Club.

Short papers by members:

"Snakes," Earl Turner, Bloomington Jr. High School.

"High Frequency Electricity," Jack Porter, Wabash High School.

"Plant Growth in a Nutrient Solution," Frances Scott, Mary Sharp, Paul Shelton, Harold Blair, Arsenal Technical School, Indianapolis.

"Basic Forms of Crystals," Robert March, Shortridge High School, Indianapolis.

Reports on progress of the Indiana Junior Academy of Science in 1939, Dean Howard E. Enders, Purdue University.

MINUTES OF BUSINESS SESSION

The annual meeting of the Indiana Junior Academy of Science was held in the Sycamore Theatre, the Laboratory School Building of the Indiana State Teachers College, Terre Haute, on November 9. The Vice-President, Donald Frier, of the Biology Club of the West Lafayette High School, presided in the absence of the President, Miss Eloise Crosby of Fort Wayne. A paper, "Interesting Facts About Animals," illustrated by slides, was given by Jack Reeves of the Lew Wallace High School of Gary. Mr. William Hopp substituted for Dr. William P. Allyn,

who was unable to appear because of illness, and gave the principal address, "Indiana Fauna," demonstrated with two reels of motion pictures. Armistice Day was observed at 11 o'clock. At that time the members of the Academy stood facing the east for a moment of silence.

Dr. H. E. Enders of Purdue University explained the present conditions upon which one girl and one boy from the Academy would be selected by the members of the Council for Honorary Membership in the American Association for the Advancement of Science. Dr. Enders also explained the advantages of membership in this organization. Ruth Downey of the Science Club of the George Washington High School, Indianapolis, and Robert Bennett of the Science Club of the Mishawaka High School were selected for these Honorary Memberships.



ROBERT BENNETT
Science Club
Mishawaka H. S.,
Mishawaka

RUTH DOWNEY
Science Club
G. Washington H. S.,
Indianapolis

C. O. PAULEY
Senior Councilor
Valparaiso H. S.,
Valparaiso

Following this portion of the program, election of officers for the coming year was held. The officers chosen were, *President*, JACK WILKIE, Elmhurst High School, Fort Wayne; *Vice-President*, DORIS SMITHA, George Washington High School, Indianapolis; *Secretary*, ROBERT KARLER of the Mishawaka High School. Mr. A. B. Krom of Wabash High School was elected member of the Council for the period 1939-1944, to succeed C. O. Pauley, Valparaiso High School, whose term expired.

After the noon intermission, Miss Anna Inskeep of West Lafayette High School presented a recommendation of the Council regarding the future selection of A.A.A.S. Honorary members. The recommendation is as follows: (1) That sponsors send nominations of candidates, plus full credentials, to the Senior Councilor at least two weeks before the annual meeting; (2) That the nominees be present at the annual meeting; (3) That they present an exhibit or a paper or some other evidence of their work at the annual meeting.

The above recommendation was accepted with the reservation that, due to the lack of time to hear all papers, it may not be feasible for all to show evidence of their work.

Mr. M. M. Williams, Sponsor of the General Science Club of the

Bloomington High School, gave an enlightening discussion on "What Makes a Live Club?"

Dr. Enders outlined a program for the member clubs to follow during the year 1939-1940. Ten-minute papers were then presented by members of various clubs.

Six new accessions to membership in the Junior Academy of Science were announced:

1. Otter Creek Jr. Acad. of Science, North Terre Haute, Prevo L. Whitaker, Sponsor.
2. Phi-Bi-Chem Club, Lawrenceburg, H. P. Harrison, Sponsor.
3. Science Club, Central High School, South Bend, O. C. Osborne, Sponsor.
4. Biology Club, Jefferson High School, Lafayette, Kenneth Dobelbower, Sponsor.
5. Junior Science Club, Laboratory School, Indiana State Teachers College, Terre Haute, Geraldine Shontz, Sponsor.
6. State High Discovery Club, Senior High School, Terre Haute, Walter Woodrow and Frank Briggs, Sponsors.

It was announced that the next meeting of the Indiana Junior Academy of Science Clubs would be held at Ball State Teachers College, Muncie, in 1940.

One hundred twenty Junior Academy members and sponsors were in attendance.

The meeting adjourned at 4 o'clock.

DONALD FRIER, *Acting President.*

JAMES BELTZ, *Secretary.*

EXHIBITS

The exhibits were installed Saturday morning. Keen interest was manifested by members of the visiting clubs as well as those who demonstrated their own exhibits. The following exhibits were prepared:

1. Otter Creek Junior Academy of Science Club, Terre Haute, Prevo L. Whitaker, Sponsor: Insect collections; brain dissections; crystal (chrome-alum); how to make insect net and Riker mount; tusk of mammoth.
2. Edison Academy of Science, Thos. Edison Jr. H. S., Hammond, Mac McCowen, Sponsor: Blue-printing; insect collections; wild flower herbarium; microscopic slides; leaf herbarium.
3. Phi-Chem Club, Elmhurst H. S., Fort Wayne, Ruth Wimmer, Sponsor: The chemistry of cosmetics; model airplane.
4. Geography Council, North Side High School, Fort Wayne, Fred J. Breeze, Sponsor: Maps showing drainage changes in vicinity of Fort Wayne.
5. Science Club, West Lafayette High School, Anna Inskeep, Sponsor: Silk moths.
6. Biology Club, Lew Wallace High School, Gary, Lola Lemon, Sponsor: Insect collections; leaf collections; slides.
7. Science Club, George Washington High School, Indianapolis, J. H. Otto, Sponsor: Maple leaf collection (both cultivated and native); Japanese beetle; turtles.

8. Science Club, High School, Mishawaka, Darl F. Wood, Sponsor: Working model of lime kiln; periodic chart of the elements; bird slides; flora of house gardens, catalog; finger-, hand-, and footprints.

9. General Science Club, Bloomington High School, M. M. Williams, Sponsor: Snakes; radio; chimes; artificial gas; pressure in liquids; Archimedes' principle; three states of equilibrium; fossils.

10. Nature Study Club, Arsenal Technical Schools, Indianapolis, Charlotte L. Grant, Sponsor: Demonstration of plants growing in nutrient solution; fruit collection; picture made from fruits and seeds; leaf collections; programs of club and clippings of club activities; 4 boards of nature photos (28 photographs); 2 boards of club activities (19 photographs); 4 special enlarged flower photographs; 2 posters; 3 club calendars: bird, wild flower, weather.

11. Discovery Club, State H. S. Laboratory School, Terre Haute, Walter Woodrow and Frank Briggs, Sponsors: Oil thermometer.

12. Junior Academy of Science, Greencastle, F. N. Jones, Sponsor: Exhibit of photographs, photography section directed by H. M. Stewart.

JUNIOR ACADEMIES

Anderson.....	Science	1936	M. J. Brozier
*Bloomington.....	General Science (Junior H. S.).....	1931	M. M. Williams
	University School Science Club	1938	W. B. Miner
Cambridge City....	Tri Science.....	1934	J. L. Bozarth
*Crawfordsville....	Audubon Society.....	1931	Emmet Stout
East Chicago.....	Edison Club Roosevelt H. S.).....	1935	Harry Apostle
Fort Wayne.....	*Geography Council (North Side H. S.).....	1932	F. J. Breeze
	Science Club (North Side H. S.).....	1936	Vesta Thompson H. H. Michaud
	Phi-Chem Club (North Side H. S.).....	1937	H. A. Thomas
	Phy-Chem (Elmhurst H. S.)....	1937	Ruth Wimmer
Gary.....	Biology (Lew Wallace H. S.)....	1935	Lola Lemon
Gas City.....	Science	1936	Roy McKee
Greencastle.....	Science	1936	F. N. Jones
Guliford.....	Science	1936	L. B. Willis
Hammond.....	Edison Acad. of Sci. (Thos. Edison High School).....	1937	Mac McCowen
Indianapolis.....	*Crispus Attucks High School (Biology).....	1931	C. E. Ransom
	Radio		A. C. Cox, G. W. Wade and L. C. Parker
	Zoology		
	Chemistry		
	*Technical Schools—Nature Study	1932	C. F. Cox Charlotte L. Grant
	*Shortridge—Chemistry	1931	Lois Martin
	George Washington Jr. H. S.—Science.....	1937	J. H. Otto
Lafayette.....	Biology—(Jefferson H. S.)....	1939	Kenneth Dobelbower
Lawrenceburg.....	Phi-Bi-Chem	1939	H. P. Harrison
Lowell.....	Science	1935	C. N. Seeright
Madison.....	Science	1938	Evans Cottman

Marion.....	Science	1936	Mrs. Pauline Mayhugh
Mishawaka.....	Science	1936	Darl F. Wood
Montmorenci.....	Jr. Acad. of Science.....	1933	I. W. Vance
Mooreville.....	Science	1936	Fitzhugh Lee
Muncie.....	Science (Blaine Jr. H. S.).....	1934	F. Kyzer
New Albany.....	Jr. Acad. (Jr. High School)...	1935	Gladys Knott
North Madison....	*Hilltop Nature Study.....	1931	V. Shoemaker
North Terre Haute..	Otter Creek Jr. Acad. Science..	1939	Prevo L. Whitaker
Paoli.....	Science	1935	O. R. Whitlock
South Bend.....	Science Club (Central High School)	1939	O. C. Osborn
Terre Haute.....	Jr. Science Club (Labora- tory School).....	1939	Geraldine Shontz
	State High Discovery Club Senior H. S., Laboratory	1939	Walter Woodrow and Frank Briggs
Tipton.....	Junior Academy of Science Club.	1933	W. D. Hiatt
Valparaiso.....	*Science	1931	C. O. Pauley
Wabash.....	Science	1936	A. B. Krom
West Lafayette....	Science (Biology).....	1933	Anna Inskeep

*Charter members.

MEETINGS OF RELATED GROUPS

As has been the custom for several years, members of the Academy interested in entomology and systematic botany held informal meetings on Saturday forenoon, November 11.

Entomology.—The meeting was called to order by P. T. Ulman, chairman. No formal papers were presented, but brief reviews of the past year's work were presented by A. C. Kinsey, Indiana University; L. F. Steiner, of the United States Department of Agriculture, stationed at Vincennes; and a number of workers connected with the Department of Agriculture or with Purdue University and stationed at Lafayette.

The Indiana State Teachers College, Earlham College, and Butler University were represented by students who gave reports on classroom activities in entomology.

L. F. Steiner was elected chairman of the group for 1940.

Systematic Botany.—The meeting was called to order by Fred A. Loew, chairman. The program consisted chiefly of a discussion of "The Limitations of the Distribution of Vegetation in Indiana." Ralph M. Kriebel gave a report on the summer field meeting held in Southwestern Indiana in September. Taxonomic notes on some Indiana plants, prepared by R. M. Tryon, were also presented.

In the symposium on plant distribution in Indiana, the following papers were presented: *Flora of the Unglaciaded Area*, R. M. Kriebel; *Relic Colonies and Boreal Flora*, Winona Welch; *The Prairie Flora*, Scott McCoy; *Dune Area and Coastal Plain Flora*, Naomi Mullendore; *Post-Glacial Flora*, J. L. Potzger. These were discussed informally as far as time would permit.

A growing interest in the summer field meetings was expressed, and suggestions were made as to the one to be held in 1940.

Paul Weatherwax was elected chairman for 1940.

NEW MEMBERS 1939

Allen, Donald E., 415 Maple Street, West Lafayette.
Banning, John W., R. R. 3, Attica.
Barbee, Miss Rula E., R. R. 2, Terre Haute.
Benninghoff, William, 2 Rutland Street, Cambridge, Mass.
Breneman, Dr. W. R., Indiana University, Bloomington.
Briggs, Harry E., 1330 South Fifth Street, Terre Haute.
Brost, Sister Josepha, St. Francis High School, Lafayette.
Burns, Raymond E., 213 N. Washington, Knightstown.
Campbell, William G., 104 Woodlawn Avenue, Crawfordsville.
Carlson, Dr. J. F., Purdue University, West Lafayette.
Conner, Miss Miriam E., 1027 Maple Avenue, Terre Haute.
Cowan, Dr. J. C., 210 E. Walnut, Greencastle.
Dawson, Dr. Ray F., 1009 S. College Street, Greencastle.
Dobelbower, Kenneth H., 628 N. 18th Street, Lafayette.
Doran, Ray L., 213 University Street, West Lafayette.
Easton, William Heyden, Box 174, Bedford.
Edwards, J. Gordon, 2834 Carrollton Avenue, Indianapolis.
Eisenmenger, Sister Mary Petrona, Saint Francis High School,
Lafayette.
Elving, Dr. Philip J., Purdue University, West Lafayette.
Ervin, Robert Francis, 814 E. Madison Street, South Bend.
Fender, Hollis Blair, 715 West 13th Street, Bloomington.
Forsyth, Max Allyn, 714 S. 8th Street, Terre Haute.
Greenwood, Henry R., 804 E. Main Street, Washington.
Groves, Miss Carol Louise, Indiana University, Bloomington.
Guthrie, Andrew, Purdue University, West Lafayette.
Hamp, Frank A., 3251 Baltimore Avenue, Indianapolis.
Harris, Chauncy D., 624 East 8th Street, Bloomington.
Harris, Miss Louise, R. R. 1, West Terre Haute.
Harrison, Prof. H. P., 487 Ridge Avenue, Lawrenceburg.
Heap, George E., Farmersburg.
Hinkle, Miss Ruth, 427 S. Troll Street, Sullivan.
Hunter, Dr. Loraine, Clarksville, Tennessee.
Johnson, Miss Joy Dillistin, 840 DeGraw Avenue, Newark, New
Jersey.
Johnson, Paul E., R. R. 2, Summitville.
Josey, Dr. Charles C., Butler University, Indianapolis.
Killeen, John Anacletus, 116 North C Street, Livingston, Montana.
Koch, Dr. G. David, Indiana State Teachers College, Terre Haute.
Kuonen, Charles E., 821 S. Grant Avenue, Crawfordsville.
Long, Dr. Alma, Purdue University, West Lafayette.
McCaskey, Miss Lois, 3551 Washington Blvd., Indianapolis.
McCowen, Max, 1554 Second Avenue, Terre Haute.
Miller, Miss Dorothy C., R. R. 4, Box 1A, Indianapolis.
Morris, D. Markland, 705 S. 14th Street, Richmond.

Morris, Miss Inez, Indiana State Teachers College, Terre Haute.
O'Neal, Mrs. Perry, 1040 W. 42nd Street, Indianapolis.
Osterman, Henry, 511 W. 6th Street, Seymour.
Ostrander, Dr. Allen R., 218 Bloomington, Greencastle.
Peters, Sister Mary Josephine, St. Francis Convent, Lafayette.
Piety, Elbert Warrick, R. R. 2, Farmersburg.
Plew, Wayne F., 214 West Donaldson, Sullivan.
Reyniers, Prof. James A., University of Notre Dame, Notre Dame.
Reynolds, Harold W., Washington.
Rose, L. Sebastian, 2236 Shelby Street, New Albany.
Sample, Dr. James H., Indiana Central College, Indianapolis.
Sandground, Dr. J. H., Eli Lilly & Company, Indianapolis.
Seaman, Lyle S., Wabash College, Crawfordsville.
Seifert, Miss Laverne, R. R. 1, Mt. Vernon.
Shields, Miss Veva, 220 E. Indiana Avenue, Bloomfield.
Shively, Dr. L. S., 2110 W. Jackson Street, Muncie.
Smith, Charles G., 1434 Haugh Street, Indianapolis.
Smith, Mrs. Fred S., 5640 Guilford Avenue, Indianapolis.
Spangler, Walter B., 210 West Jefferson, Albion.
Sparks, George R., 1724 Garfield Avenue, Terre Haute.
Vestal, Dr. A. G., University of Illinois, Urbana, Illinois.
Welborn, Dr. E. L., Indiana State Teachers College, Terre Haute.
Whitaker, Prevo L., R. R. 5, Terre Haute.
Wise, Robert E., 218 North 6th Street, West Terre Haute.
Zahnle, Vincent, 120 Sheridan Place, Lake Bluff, Illinois.

NEW JUNIOR CLUBS 1939

Jefferson High School Science Club, Jefferson High School, Lafayette.
Phi-Bi-Chemi, Lawrenceburg High School, Lawrenceburg.
Otter Creek Junior Academy of Science, Otter Creek High School, North Terre Haute.
Junior Science Club of Laboratory School, Indiana State Teachers College, Terre Haute.
State High Discovery Club, Laboratory School, Indiana State Teachers College, Terre Haute.

NECROLOGY

DOMINIC JOSEPH CANNON

Scranton, Pennsylvania
May 4, 1879

Notre Dame, Indiana
May 4, 1939

The Reverend Dominic Joseph Cannon, C.S.C., received his early education in the parochial schools of his native city, Scranton. His collegiate studies were made at Notre Dame and his theological course at Holy Cross College, an institution affiliated with the Catholic University of America in our national capital.

He was ordained to the priesthood on December 18, 1913. Until illness forced his retirement, he was active in the classrooms and laboratories of the institution, the Congregation of the Holy Cross, and as a member he took charge of the religious community. After a very successful career as teacher of physics in the University of Portland, Oregon, he transferred to the University of Notre Dame.

Father Cannon, while recognizing the value of research and doing all in his power to foster it among his students, was pre-eminently a teacher. He was at his best in the lecture hall, and it is as an inspiring and inspired teacher that his students and his colleagues will remember him.—*F. J. Wenninger.*

HENRY CHANDLER COWLES

Kensington, Connecticut
February 27, 1869

Chicago, Illinois
September 12, 1939

On September 12, 1939, there passed away in Chicago one of the most prominent members of the Academy, Henry Chandler Cowles. Born in Kensington, Connecticut, on February 27, 1869, he received his early education in the schools of his native state and then entered Oberlin College, from which he graduated in 1893. He taught in Gates College for a year and then went to the University of Chicago on a fellowship with geology as his major interest. However, with the reorganization of the Botany Department at Chicago in 1896, when John M. Coulter was called there as Head, Dr. Cowles came under the influence of Dr. Coulter and a little later Charles Reid Barnes, two of the celebrated ABC triumvirate in botany, all members of the Indiana Academy, with the result that he received his doctorate in 1898, with plant ecology as his major interest. He became a member of the Department of Botany in Chicago in 1897, beginning as an assistant and finally becoming a full professor in 1911. He was chairman of the Department from 1925 to 1934, when he was retired with the rank of Professor-Emeritus.

A natural-born teacher, affable and charming in personality, and a man who attracted students to him through his jovial disposition and deep, masterly insight into his subject, Dr. Cowles became a leader and

world authority in ecology. The Ecological Society of America was founded largely through his efforts in 1914, and he wrote numerous articles and several books and textbooks which are classic. In recognition of his leadership in plant ecology he was made president of the section of phytogeography and ecology at the meeting of the International Congress at Cambridge, England, in 1930. An exponent of the field trip method of study and research, he frequently led students on field expeditions lasting from days to several weeks.

Dr. Cowles received many honors. He was president of the Botanical Society of America in 1922, president of the Association of American Geographers in 1910, vice-president of Section G of the American Association for the Advancement of Science in 1913, president of the Ecological Society in 1918, president of the Chicago Academy of Sciences from 1923 to 1934, and a member of many other scientific organizations. He was associate-editor of the *Botanical Gazette* from 1898 to 1926 and its editor from 1926 to 1934. Starred in *American Men of Science*, he was further honored by having the July, 1935, issue of *Ecology*, official journal of the Ecological Society, dedicated to him, it being filled with articles by his students and colleagues from this and several European countries.

Dr. Cowles was one of that distinguished group of American scientists who received their inspiration and encouragement from Indiana's celebrated scientists of the Jordan-Arthur-Coulter period. Primarily field men, who went directly to nature for their study, this great group—Jordan, Arthur, Coulter, Eigenmann, Branner, Everman, Cowles, and others—has left such an impression on modern science that their activity and interest in the Indiana Academy of Science redounds to its glory. This group is rapidly passing from the scene, and, with the death of Henry Chandler Cowles, international science again suffers an irreparable loss.

MORTON W. FORDICE

Putnam County, Indiana
May 26, 1864

Putnam County, Indiana
March 1, 1939

Morton W. Fordice, one of the founders of the Indiana Academy of Science, was born on May 26, 1864, on a farm in Putnam County, Indiana, and passed away near the place of his birth on March 1, 1939. Entering Indiana University as a young man, he early came under the influence of David Starr Jordan, under whose supervision as a special student he wrote a number of papers on ichthyology published in the *Journal of the Philadelphia Academy of Science* and elsewhere. Returning to the farm shortly after his graduation in 1886, he maintained throughout the rest of his life a love for and an interest in scientific farming and scientific experimentation. In 1893 he married Miss Ella G. Williams, who survives him, together with two sons and two daughters. Both he and Mrs. Fordice were active in Republican politics of the county and district. While Mr. Fordice had been inactive in the Academy for many years, he nevertheless was actively interested in the scientific

progress of the state and was recognized as a progressive, influential farmer of broad interests, sterling integrity, and civic worth. His passing was a distinct loss to the community in which he had spent his whole life.

THOMAS EDWARD MASON

Boone Grove, Indiana
October 1, 1883

Chicago, Illinois
May 26, 1939

On May 26, 1939, the Indiana educational world was shocked to hear of the death in a Chicago hospital of Dr. Thomas E. Mason, a native of Indiana and a member of the Purdue University staff for twenty-five years. Dr. Mason, born October 1, 1883, in Boone Grove, Indiana, was identified with Indiana education all his life. Graduating from Indiana University in 1905, he became a Fellow at Indiana in 1911 and received the A.M. degree in 1912 and the Ph.D. degree in 1914, being the second person to receive the Ph.D. degree in mathematics from that university. He joined the mathematics staff at Purdue in 1914. During the World War he served on the Y.M.C.A. staff in France. He also spent two years in study in England. His chief interest in mathematics was in number theory and difference equations, and he had written and published several research papers in those fields. He had offered graduate courses in mathematics at Purdue for a number of years and was a joint author of two textbooks which are still widely used.

Dr. Mason was very active in scientific circles in the state and was active in the formation of the mathematics section of the Academy. He was a member of Phi Beta Kappa, Sigma Xi, the American Mathematical Society, the Mathematical Association of America, and the American Association of University Professors and a Fellow of the American Association for the Advancement of Science. He was very active in church work, being a member of the Presbyterian church, and for many years he was superintendent of the Sunday School of that denomination in Lafayette.

He was twice married, his first wife passing away in 1936. He is survived by his second wife and two daughters.

Thomas E. Mason was one of those rare individuals of broad, scholarly interests, whose home was always open to his friends. Many a lonely instructor just coming to Purdue was welcomed by Dr. and Mrs. Mason and received encouragement and friendly advice until he was established. A lover of art and rare books, his home was a place of interest to those who enjoyed his hospitality. He was a born teacher of fine and gracious personality, with a large following of students and alumni, and with his death Purdue loses one of its outstanding, influential men.

ARTHUR G. MITTEN

Brighton, England
March 13, 1866

Goodland, Indiana
November 23, 1938

Arthur G. Mitten was born on March 13, 1866, in Brighton, England, and came to the United States with his parents when he was nine years

old. At the age of twenty he entered the employ of the Chicago and Eastern Illinois Railroad and remained with that company until 1920, when he returned to Goodland and engaged in the purchase and improvement of numerous Benton county farms. A brother of the late Thomas E. Mitten, of the Philadelphia Transit Company, he was at the time of his death president of the Mitten Memorial Library and of Foster Park, both gifts to the city of Goodland by his brother. He was affiliated with the Goodland Methodist Church.

Mr. Mitten was deeply interested in history and archeology and was well known as a collector of historical data. He had served as a vice-president of the Indiana Historical Society. On account of his extensive researches in the history of the old Northwest Territory and William Henry Harrison, he was honored by Vincennes University with the degree of Doctor of Letters.

He was married in 1889 to Miss Adda J. Britt, who survives him; a son and a daughter also survive him.

Arthur G. Mitten was a typical dignified, distinguished English gentleman whose home was full of interest on account of its library and scientific collections. A most gracious host and a friend to everybody in his community, he was ever alert to civic needs and did much to help his community, which endeared him to all those who knew him. In his death Indiana suffers the loss of one of its leading citizens, and the Academy loses a worthy member whose intense interest in science, pursued as a hobby, accomplished much of scientific and historical value.

JOHN L. REEVES

Kentland, Indiana
September 7, 1913

Lafayette, Indiana
June 2, 1939

John L. Reeves was born in Kentland, Indiana, on September 7, 1913, and died of an accidentally self-inflicted gunshot wound on June 2, 1939. Most of his boyhood was spent in Lafayette, but he later moved with his parents to Brookston where he graduated from high school. Becoming interested in science, he entered Purdue University where he received his degree in biology in 1936. On account of the excellence of his work he received an assistantship in the Biology Department at Purdue, which allowed him to continue his studies so that he received his Master's degree in 1938. Early in 1939 he resigned his assistantship in order to accept a teaching position in Ferris Institute, Big Rapids, Michigan. He had just returned home on his vacation a short time before his death. He is survived by his parents.

John L. Reeves was a young man of considerable scientific promise who had just begun an interesting career with that enthusiasm and persistence which was earning for him the admiration and respect of his fellow workers. In his untimely passing the cause of science suffered the loss of a young man whose scientific future seemed assured.

ELDYN EVERETT VANLONE

Jefferson, Wisconsin
January 11, 1895

West Lafayette, Indiana
April 5, 1939

In the passing of Eldyn E. VanLone from a heart attack while officiating at an installation meeting of the Optimist Service Club, on April 5, 1939, Purdue University lost one of its outstanding younger scientists. Dr. VanLone was born at Jefferson, Wisconsin, on January 11, 1895, and spent his early life there. He graduated from the University of Wisconsin in 1923; he also received his Master's degree in 1924 and his Ph.D. degree in 1931 from that university. He was an assistant in genetics at Wisconsin until he came to Purdue in 1932 as assistant professor of animal husbandry. In 1926 he was married to Miss Adeline Bakker, who survives him, together with his mother, one brother, and one sister.

Dr. VanLone had done and was doing outstanding research work in animal husbandry and had published a number of noteworthy papers on mammalian genetics, sterility, and the physiology of reproduction. Possessed of a pleasing personality, a thorough knowledge of his subject, and unusual teaching ability, he had attracted to him a number of students who were interested in genetical research in the breeding of live stock. He was also interested in the social and civic life of his community and was a leader in civic club activities, being a past president of the Lafayette Optimist Club.

He held memberships in the American Association for the Advancement of Science, the American Genetics Society, the American Society of Animal Production, Sigma Xi, and Alpha Gamma Rho social fraternity. Dr. VanLone was a veteran of the World War.

It is only with genuine regret that one records the passing of a scientist of Dr. VanLone's ability and prospect, and his loss to Purdue University, the Academy, and the state will be keenly felt.

PRESIDENTIAL ADDRESS

Parasitism as a Way of Life

TRUMAN G. YUNCKER, DePauw University

Of all the various factors which influence the phenomenon of life as it evidences itself in the multitudinous variety of living organisms, those involved in the acquiring of a proper and sufficient amount of food material are unquestionably most significant. If we eliminate from consideration certain accessory substances such as minerals, those things which serve as foods, in the commonly accepted sense, are organic in nature. They supply organisms with materials for construction and repair and at the same time release energy under the destructive action of the respiratory function. Every living organism, from the most minute unicellular individual to the complex higher forms, is dependent upon a more or less continuous supply of such organic compounds which can serve these functions.

It would naturally be expected that living organisms which occur in such amazing variety of size, form, and degree of complexity would also exhibit wide differences in the manner in which they acquire their foods. When the processes and conditions involved are carefully analyzed, however, it is discovered that there are few, if any, fundamental differences in the nutritional habits of most living organisms. The foods are commonly similar in nature; they enter into the cells under essentially similar conditions and perform comparable functions for the organisms. There may be, of course, differences in the physical or mechanical features of organisms, which depend for the most part upon the presence or absence of the pigment chlorophyll, the complexity of the organism, and the type of habitat in which it lives. Green plants are rightfully recognized as the source of organic foods for most other non-green organisms, both plants and animals. It is sometimes assumed that such green plants are capable of maintaining life independent of assistance from other organisms. This, however, is found to be only partially true when a study is made of their dependence upon various materials which are obtained from the environment and in the preparation of which other organisms have played important rôles. The food required by non-green organisms is obtained either saprophytically from the decomposition of the remains of dead plants and animals, which have fed upon plants, or parasitically from intimate contact with a living organism. It is often considered that the parasitic or saprophytic manner of securing food is a degraded type of nutrition and that the only self-respecting method is by means of the photosynthetic process practiced by chlorophyll-bearing plants. Such heterotrophic plants are believed to be "coasting down an inclined plane of degeneracy which will ultimately result in their extinction." Certain atrophies and morphological changes associated with the parasitic habit are commonly indicated as supporting this assumption. With this point of view exception may be taken. The atrophies

found in plants associated with a dependent mode of life are, in large part, merely reductions of features which were originally developed in association with and for the purpose of aiding in the photosynthetic function. Mankind, which we in our egotism believe represents the ultimate in organic evolution, presents an excellent example of successful nutritional dependence. Furthermore, the numerous atrophies and morphological changes found in man, as compared with the lower animals, are usually not considered to represent degradation but rather to have resulted from more or less normal evolutionary changes brought about in consequence of changing environmental conditions and uses.

The term parasite is often used in a broad sense in referring to certain types of dependence among humans usually with a derogatory connotation implying an unpraiseworthy degree of laziness. This concept of parasites as representing undesirable members of human society has also, by popular usage, been applied to dependent individuals among the lower groups of organisms. This is illustrated, for example, by the following statement by one author:

Parasitic plants indicate the length to which plant life will go in its determination to exist, but they also "point a moral" in which the examples elicit a degree of contempt. A parasite lives at the expense of another, doing no worthy labor, but always managing to propagate its degenerate kind.

When used in reference to humans the word parasite implies certain psychological, sociological, and ethical relationships quite foreign to any that are possible among organisms below the evolutionary level of mankind. The term parasite when applied to lower forms of life should always be used in a more technical sense. It should denote definite physiological, morphological, and ecological features and associations and thus possess a more exact and restricted signification. That dependence of one individual upon another is *per se* always bad and consequently undesirable would appear to be an assumption quite out of line with facts. Dependence of individuals upon each other, directly or indirectly, is a relationship which is common throughout all groups of living organisms. Whether the benefits of this relationship come from a direct physical contact or through some intermediate agency and whether the association results in injury to either of the organisms or not would seem to be insignificant distinctions when the basic nutritional aspects of the question are considered.

The world and all the things thereof may be divided into the two categories of the inorganic or non-living and the organic or carbon-containing substances characteristic of the composition of all living organisms. It appears probable that the nature of the primitive or early phases in the earth's development was wholly inorganic and that organic substances came into existence at some subsequent but as yet unknown period. It is in the realm of the organic that life primarily centers and upon which our interest is chiefly focused.

The locale of all life processes—the vehicle for the bearing of that which we recognize as life, as all students of science know—is the nearly transparent, somewhat viscid, and altogether quite unimpressive-appearing substance now known as protoplasm, which is the indispensable material of the living cells of all organisms. Protoplasm

has long been, and still remains, the object of intensive investigations concerning the nature of its chemical, physical, and biological being. Much has been discovered about it. The phenomenon of heredity, the reactions to environmental forces, and many other biological characteristics of cells are becoming common knowledge. The principal classes of chemical constituents are generally recognized at the present time. Much has been learned about the physical make-up of cell structure, although some details still remain puzzling and are the bases of various theories which lend interest to further research.

Unquestionably, the most interesting feature of protoplasm is its capacity for carrying on those reactions and adjustments which we consider to be criteria of life. It is able to grow and increase itself and to reproduce in a variety of ways. It is sensitive to the innumerable environmental stimuli which impinge upon it and is able to adjust itself favorably in response to them. That life depends for its being upon a very delicately balanced system of biological, chemical, and physical factors is obvious to any careful observer. It is a simple matter to destroy life by various suitable means. Lethal forces unquestionably bring about physical and chemical changes and upset the balance so essential for its continuance. Precisely what has occurred is problematical to a large extent. It is sometimes difficult to detect any conspicuous structural difference between a living cell and one that has been carefully killed. If one could accurately identify and correctly interpret the changes which occur during senescence and death, the nature of life itself might be revealed, and man could perhaps develop a method of duplicating protoplasm and of endowing it with vitality.

How and when life first appeared are questions seemingly not amenable to satisfactory scientific solution. Students of organic evolution are agreed, in the main, that it probably originated in a very simple, non-organized mass of protoplasmic-like material. That this original living matter did not possess the form and specialization evident even in the most primitive and simple organisms now extant would seem to be a logical inference. It could be assumed that primal protoplasm was entirely similar to that which now exists. But can such an assumption be justified? There are many requirements essential to the maintenance and continuance of life. One of the most fundamental is that there be a supply of sufficient energy. Did primitive protoplasm utilize the same specific energy sources as does its modern descendant? Processes of evolution are inherent in protoplasm itself. It is not inconceivable, therefore, that primitive protoplasm may have been able to function without the same complexity of energy requirements that we now find.

It is reasonable to conclude that primal protoplasm was necessarily endowed with the ability to grow and to reproduce itself, to nourish itself through some synthetic process, and to adjust itself in response to environmental stimuli. Whether chlorophyll originated contemporaneously with the first protoplasm or came into being at some later date is a question of considerable significance when we consider the phylogenetic relationship of the lower plants. Protoplasm, as we now

understand it, requires organic, carbon-containing compounds for food and a source of energy. Since the origin of chlorophyll, the chief source of such organic matter has been from green autotrophic plants. They are able, by the so-called photosynthetic process, to unite the carbon-dioxide of the air with water and to incorporate a part of the solar energy in the resulting carbohydrate molecules. The more complex foods such as proteins and fats are further elaborated presumably by non-photosynthetic processes through additions to and changes in these basic carbohydrates. While it is now true that practically all organic food is the product of green plants, it is, at the same time, known that a small number of fungi are able to synthesize food by utilizing energy obtained from the oxidation of inorganic compounds. Also, a few species of fungi are able to utilize solar energy and photosynthesize with pigments other than chlorophyll. These synthetic processes on the part of chlorophyll-less autophytes are now quantitatively unimportant. They are, nevertheless, of great significance when one canvasses the possible sources of food-stuffs in a hypothetical pre-chlorophyll period of organic life.

To many students of the question it appears that organic life probably existed for an indefinite period of time previous to the genesis of chlorophyll pigments. The sources from which these primitive organisms received their requisite food are not easily identified from a study of conditions now prevailing. The possibility of their dependence upon chemosynthesis or photosynthesis with non-chlorophyll pigments appears to be an inviting and plausible theory, inasmuch as these processes are both operative in some of our most primitive non-green plants of today. Unfortunately, it is impossible to obtain any definite knowledge of the physiology of primitive protoplasm. It seems reasonable, however, to assume that even in the pre-chlorophyll age at least some individuals must of necessity have possessed a synthetic process and that others at the same time undoubtedly acquired the ability of utilizing the products of such autotrophic species in a parasitic or saprophytic manner.

The origin of chlorophyll and its introduction into the cell structure and its utilization in the production of elementary, energy-carrying foods had an extremely great and far-reaching influence upon the evolutionary process. Organisms which until this time, according to the opinion of some, had been progressing along a more or less common highway of evolution became differentiated into the great plant and animal kingdoms. Evolutionary advance now proceeded along two progressively diverging lines of development, with green plants destined to become the manufacturers of foods for virtually all organisms lacking such pigmentation. The distinction is sometimes made between plants and animals to the effect that plants make food and animals do not. This differentiation is, of course, superficial and misleading when one considers the great numbers of plants which are as dependent upon outside sources for their foods as are animals.

Division of labor in unicellular organisms is obviously impossible, and, consequently, the single cell is required to carry on all of the physiological processes essential to the maintenance of its life and reproduction. One of the early stages in the evolutionary development of living organisms was the grouping of a number of cells into a colonial

association. In many such colonial arrangements each cell apparently carries on its functions as completely as though it were wholly separate. Eventually, however, some cells became specialized for the purpose of doing work for the common good of the cell group, and we have then not a colony but a simple multicellular organism.

Chlorophyll is generally present in all or nearly all of the cells of primitive plants. As evolution progressed, however, plants became increasingly more complex with the photosynthetic function more and more restricted to special chlorophyll-bearing cells. One of the results of the specialization of the photosynthetic process is apparent in its effect upon the morphology of the plant. Leaf or leaf-like structures definitely designed to facilitate photosynthesis are a prominent feature of nearly all of our higher plants and are lacking only in the more primitive groups or in plants over which certain environmental forces have become dominant.

In the physiology of nutrition, if we except the synthetic processes, each cell of an organism acts essentially as though it were a separate unit. Materials entering any cell must first be rendered soluble before they are able to pass through the protoplasmic membranes, regardless of the phylogenetic position of the organism. The entrance of materials into the cell of any simple organism is believed to obey basic physical and chemical requirements similar to those necessary for their passage into any of the living cells of our most complex multicellular organisms. This appears to be true whether the movement be from outside the plant, as from the soil into the roots, or between adjacent cells within a tissue. The distinction commonly made between saprophytism and parasitism lies not in differences of food substances nor in the manner of acquiring them but solely on the basis of whether the food is obtained directly from an organism that is alive or from a non-living source. No organism is capable of utilizing and incorporating living substance into its own body. It would appear, therefore, that all foods are necessarily inanimate when they enter a cell. When organic material is taken from a living source there results in most cases a harmful or at least a detrimental effect on the host, inasmuch as it loses substances which were destined for use in the physiology of its own cells. The relationship which exists between the chlorophyll-containing cells of multicellular organisms and those which are colorless is similar in many respects to that prevailing between the host and its parasite. The colorless cells are as dependent upon their photosynthetic neighbors for basic carbohydrates as is a parasite upon its host. In this relationship, however, the nutritional balance between the various units is maintained in such a manner that the green host-cells apparently are not injuriously affected to any extent.

It is not uncommon to find two or more species of algae living in close association. It appears possible that under suitable conditions one of the species might obtain some food from its associates in a manner somewhat comparable to that in which the non-green cells of higher plants obtain theirs. Such food transfer might involve slightly different physical factors, but it would not, seemingly, need to differ materially from an exchange between the closely associated cells of an algal colony

or between the green and non-green cells of a multicellular plant. The development of the simple haustoria exhibited by species of fungi would not appear to present any difficult evolutionary problem.

Fungi have developed along evolutionary lines quite distinct from those of their algal relatives. They are able to thrive in environments and under conditions impossible for green plants. This variation of habitat, as well as other factors, has probably played an important rôle in influencing the development of the reproductive habits and other characteristics peculiar to the various fungal groups. It is probable that parasitism appeared very early in the evolutionary development of living organisms. When once established as a specific characteristic, it has persisted and become amplified in succeeding groups. The study of evidences of pathology in fossilized plant and animal remains is interesting in itself but would not appear to throw much light on the origin of parasitism. There can be no sharp lines of difference drawn between parasitism and saprophytism, and the question as to which is more primitive does not seem to be significant. A number of dependent organisms are known which are able to adjust themselves either to a parasitic or to a saprophytic mode of existence as conditions demand, and it seems reasonable to assume that the earliest forms of dependence may have been as readily facultative.

Interesting examples of parasitical relationship are those existing between the gametophytic and the sporophytic generations of plants exhibiting alternation of generations. In general, the gametophyte of the lower plants bears chlorophyll and supplies a more or less dependent sporophyte with its necessary food. This nutritional dependence on the part of the sporophyte is illustrated by many bryophytes. In this group the sporophyte usually lacks chlorophyll and is commonly attached to a more prominent and photosynthesizing gametophyte by a haustorium-like structure called the "foot." The sporophytes develop chlorophyll and assume a degree of nutritional independence among some of the higher bryophytes, but all remain dependent to some extent for at least their water and mineral requirements. In the pteridophytes a complete reversal of sporophytic and gametophytic relationship occurs with the sporophyte becoming the dominant phase. While it apparently never becomes completely independent of the gametophyte for at least some of its food, especially in its early stages of development, it does assume at maturity the dominant rôle in food production for those plants evolutionarily superior to the bryophytes. The gametophytes of ferns appear to be nutritionally independent of the sporophytes. Among other members of the pteridophytes, however, there is a definite tendency towards the loss of the photosynthesizing function and the necessity of obtaining food from some external source. Some of the gametophytes of *Lycopodium*, for example, have no chlorophyll and must depend for their foods largely upon the activity of the mycorrhizal fungi with which they are invested. Among the seed plants the gametophyte remains wholly dependent upon the sporophyte. There appears to be little or no fundamental distinction, so far as nutritional factors are concerned, between the sporophyte-gametophyte relationship of many plants and that existing between a typical parasite and its host. It may not prove unprofitable

to seek answers for some of the questions involving parasitism in this field of inter-generation relationship.

It might naturally be expected that an innovation as significant as the introduction of chlorophyll into the structural and physiological make-up of cells and the advantageous photosynthetic activity resulting would become permanent features. It would appear, also, that the food problems of chlorophyll-containing organisms would be largely solved, or at least greatly minimized, by the development of the photosynthetic process and that such organisms would be reluctant to discard this apparently easy way to nutritional independence. Since its inception, chlorophyll, however, has not remained a constant characteristic of all plants possessing it, and there are many species in which it has been partially or wholly eliminated. As previously stated, the photosynthetic function is common to all or nearly all of the cells of the more simple and primitive autophytic species. However, as plants developed greater complexity and division of labor became more emphasized, the chlorophyll-bearing cells became more and more segregated. Many tissues completely lost their ability to photosynthesize and consequently were dependent upon their chlorophyll-bearing associates. Furthermore, there are numerous species distributed throughout the plant kingdom which have developed the ability of securing some or all of their food requirements from a source external to themselves. Why plants which presumably possessed chlorophyll and, hence, nutritional independence should develop some other seemingly more precarious means of securing their food is one of the interesting problems of biology. On the other hand, whenever the parasitic mode of life has been adopted, it has commonly persisted and become a permanent feature in the life of the species. There is no evidence of the abandonment of the parasitic habit after it has been once initiated. The introduction of the parasitic habit ordinarily provokes a number of morphological changes, particularly in those structures associated with photosynthesis. The chlorophyll gradually disappears, the leaves are reduced, and normal roots are sometimes replaced by haustoria.

The largest and most notable group of dependent plants is the cosmopolitan aggregation known as fungi, which is one of the most important groups of plants when considered from an economic point of view. They are comparatively simple morphologically and are believed by many to represent chlorophyll-less descendants of autophytic algal ancestors. In no other group of organisms, aside from animals, has the dependent mode of life become so prominent and well established. That their loss of independence is not seriously disadvantageous is evidenced by the large number of species and their very obvious success in competition with autophytic plants. An interesting fact, which may have some significance when considering the phylogenetic relationship of fungi, is that several species of algae have been reported as able to supplement their photosynthate by absorbing organic substances from their environment. This might be interpreted as indicating a preliminary step in the establishment of a dependent mode of nutrition. As one would expect in a large and diverse group such as the fungi, there is to be found practically every conceivable variation in nutritional re-

lationship, ranging from obligate parasitism on the one hand through various degrees of facultatism to obligate saprophytism on the other.

Parasites are commonly looked upon as being injurious to the hosts upon which they grow. There are, however, many parasite-host relationships in which the host is obviously not seriously affected and not infrequently is actually benefited by the association. The legume-nitrogen-fixing bacteria combination, the numerous mycorrhizal relationships, and many other examples illustrate such beneficial alliances. The large number of autophytic species now known to harbor mycorrhizal fungi is indicative of the advantage of this combination in which often both the fungus and the host are believed to be beneficiaries. Some higher plants have developed a dependency upon their mycorrhizal confederates to such a degree that it is difficult or impossible for them to thrive in the absence of the fungus. The fungus in such cases acts as an intermediate agent by assisting in the preparation and absorption of food substances from the soil for later utilization by the host. In *Calluna*, the Scotch heather, the mycorrhizal fungus grows abundantly in and upon the roots and may even penetrate to other parts of the plant. The heather does not thrive in the absence of the fungus, which is reported as having the ability to fix nitrogen. In the presence of an abundance of soil nitrogen, however, the fungus may become too aggressive and destroy its host. Study of the interrelation of fungus and host in cases such as the heather illustrates the complexity of the relationship and the delicacy of the balance which often exists between two such organisms. *Monotropa*, or Indian Pipe, long considered to be a rare example of a flowering plant living saprophytically upon decomposing organic matter, is now known to have its roots invested by a mycorrhiza. It is, therefore, to be considered more as a parasite upon these root fungi than as an example of a saprophyte. Thus, we have an illustration of a curious and anomalous situation where a higher plant becomes parasitic upon a fungus.

With the exception of mycorrhizal fungi and the inter-generation dependence, we find parasitism almost entirely limited to fungi and to certain flowering plants. It is exceedingly rare or lacking in the groups including the mosses and the ferns. Among the numerous parasitic species of flowering plants the variations exhibit every conceivable combination of interrelationship and dependence. The mistletoes of the family *Loranthaceae* contain chlorophyll and are dependent upon their hosts only for water and minerals. Such so-called "water parasites" represent, in the opinion of some, an early phase in the evolutionary development of the parasite which will eventually acquire the ability to absorb elaborated foods, lose its chlorophyll, and thus become completely parasitic. In the *Scrophulariaceae* or figwort family there are a number of species parasitic or partially parasitic upon the roots of other plants. Many of the genera are independent, but, on the other hand, species of *Lathraea*, for example, are completely parasitic. Species of *Pedicularis* are parasitic to a slight degree; those of the genus *Tozzia* live for part of their lives as complete parasites but eventually produce a chlorophyll-bearing aerial shoot and hence become partially independent. Selection of proper examples in this family gives a series of species illustrating

a gradual transition from complete independence to complete parasitism.

In the genus *Cassytha* of the Lauraceae and *Cuscuta* of the Convolvulaceae we have examples of comparable evolutionary development in which the parasites become attached by haustoria to the aerial stems of their hosts. It is interesting to note the similarity in habit of growth and development of the species of these two quite unrelated genera. It is not unusual for specimens of *Cassytha* to be mistaken for the more common *Cuscuta* or dodder. *Cuscuta* is an example of complete parasitism and extreme morphological modification because of its nutritional dependence. Chlorophyll is present to some extent in the stems and flowers of certain species but for the most part it is lacking; the leaves are reduced to small, inconspicuous scales, and normal roots never develop. The embryo is slender and coiled about within the seed. Upon emergence one end becomes erect and assumes the attitude of a snake in a striking position. This erect portion describes circumnutation movements which upon contacting a suitable host enable it to coil about the plant. Haustoria soon develop in the region of the coils and the parasite thus becomes firmly attached. There may be traces of chlorophyll in the seedlings of some species, but, nevertheless, if they do not soon reach a host, they perish. An interesting form of self-parasitism in the dodder has been described as occurring during the seedling stage. It has been shown that the seedling, in a few species at least, is able to elongate at the erect or anterior end and thus increase to some extent its range of search for a host by transferring and utilizing food material obtained by digestion of the posterior portion. There are many additional species of flowering plants which, likewise, show parasitical habits to a greater or lesser degree. Many of these are of considerable interest.

Many interesting problems are found in the relationships existing between parasites and their hosts. There are varying degrees of host specialization shown by different parasites and also defensive reactions on the part of some host plants which might in some cases be interpreted as a form of immunity. It is difficult to imagine an immunity in plants involving antibody formation comparable to that developed in animals. An explanation of many of the selective or antagonistic relationships is, for the most part, however, to be sought in differences in structural and chemical features and also in the osmotic dissimilarity of the host and parasite cells. It has been demonstrated in certain cases that the osmotic concentration of the cell sap of the parasite is necessarily higher than that of its host, and, unless this condition can be satisfied, it is impossible for the parasite to obtain material from the plant upon which it is growing.

Thus, as we survey the plant kingdom, we observe innumerable examples of nutritional dependence. In fact, dependence to at least some degree would appear to be much more common than is generally supposed. The use of the term independent in connection with chlorophyll-containing plants is purely relative. No organism can be said to be wholly independent and live in a state of "splendid isolation" from other organisms. It is true that green plants are able to synthesize carbon-containing compounds. It is equally true, however, that they are dependent for a number of their requirements upon the activities of or-

ganisms which inhabit the soil and which help prepare the various elements needed for the physiology of the green plant. These soil organisms, of course, are in turn largely dependent upon the compounds produced by the green plant which are made available when it dies and returns to the soil and is acted upon by the "wrecking crew" of soil micro-organisms.

The various forms of parasitism, saprophytism, symbiosis, and mycorrhizal relationships are but variations of processes between which there is no obvious or definite line of demarcation. The gradations between mycorrhizal and various symbiotic relationships are slight, as are, also, those differentiating between typical parasitism and saprophytism. It is, likewise, difficult to distinguish between a true symbiosis and the various shades of relationship known as commensalism, helotism, etc. It appears obvious that these are but variations of the same theme with slight advantages in favor of one or the other of the organisms involved. The interrelationship of organisms often depends upon a finely balanced system of factors, and, when one or more of them are altered, the relationship may be definitely changed.

The circumstances which prompt a self-nourishing plant to assume a dependent mode of life are not conspicuous. That they have been frequently operative, however, is evidenced by the numerous examples of dependent species believed to be descendants from chlorophyll-containing ancestors. It is commonly assumed that an organism which obtains its food by parasitism rather than in an autophytic manner is degenerate. The successful manner in which parasites are able to maintain themselves in a highly competitive relationship, however, casts some doubt upon this assumption. Whether parasitism represents an occasional example of retrogressive evolution, as is popularly thought, or is, perhaps, a more general condition throughout all groups of living organisms, or even representative of progressive evolution, is a question which might well be raised. Why is any successful method of securing food by plants to be considered contemptible and degenerate? The evolutionary substitution of one process or structure for another would not necessarily indicate degeneracy if such changes do not impair the ability of the organism to maintain life successfully and to reproduce. Does the evolutionary change increase the organism's capacity to live successfully and survive? This is a question which might be asked when deciding whether the direction of evolution is progressive or retrogressive. The almost limitless number of examples of nutritional interdependence of every degree would lead one to the conclusion that such dependence, which we may term parasitism in a broad sense, is to be considered in plants at least a more or less normal way of life.

ARCHEOLOGY

Chairman: PAUL WEER, Indiana Historical Society

The program of the section on archeology and the attendance at the meeting indicated a sustained interest in this field.

A significant part of the program was centered around the progress which is being made in the excavation of the Angel Mounds east of Evansville, under the direction of Glenn A. Black. This great mound group and habitation site, probably the most imposing of all prehistoric remains in Indiana, was recently purchased by the Indiana Historical Society in order that a scientific study of it could be made and its relationships to other great remains in the eastern part of the United States be determined.

The program also presented some aspects of the study now being made of the "Walam Olum," a famous Indian document believed to have been procured from the Delaware Indians living along White River, in Indiana, in 1820, and, passing from a "Dr. Ward, late of Indiana," to have fallen into the hands of Constantine Samuel Rafinesque, then a professor at Transylvania College, Lexington, Kentucky. Accounts of the "Walam Olum" were published by Rafinesque in 1836, by E. G. Squier in 1848, and by Daniel Brinton in 1885.

A paper by Dr. Thomas B. Noble, Jr., on Art and Archeology, in which he discussed some phases of his latest trip to the prehistoric Southwest, was presented with colored slides.

Paul Weer, Indiana Historical Society, was re-elected chairman of the section for 1940.

The Problem of the Atlatl

E. Y. GUERNSEY, Bedford

The "atlatl," or "throwing stick," is a simple but ingenious implement by means of which a light lance or spear may be cast with greater velocity and precision than would be possible through the use of the hand and arm alone. It provides, in effect, an extra extension of the arm and an additional lever or toggle-joint by means of which combination the propulsive force applied to the spearshaft is greatly increased. It should be considered as a weapon, being in fact a sort of counterpart of the bow.

Objection may be properly raised against the use of the word "atlatl" to apply in general to this weapon in use since remote times in some quarters of the six continents and the islands of the several seas. In Australia it is called a "woomera," and in each region where it is used it bears a different name.

To call it a "throwing stick" is likewise objectionable since the "boomerang," a "stick" which is itself thrown, is also defined as a "throwing stick." Krause, a reliable authority upon the spear thrower, raises these objections but ends by calling the weapon in all of its forms a "spear sling"—which suggests, to us at least, a use of thongs or cord, as in the ancient Greek "amentata." The French archeologists, who call it, quaintly, a "propulseur," perhaps come more closely to hitting the mark and providing a really appropriate name for the implement.

What we have here to say comprises, we admit, no more than a brief and insufficient digest of the prolific literature upon the spear thrower as it has been and is now still used in various parts of the world. The two or three years devoted to its study have convinced us that we have, at best, merely scratched the surface of an intriguing field for research. Experiments in its actual use have created an unbounded respect for the versatility of this primitive implement and have provided a decidedly better understanding of its perquisites and possibilities.

The problems of the "atlatl," which are many and varied, may start perhaps with that of the ultimate discovery of its common original source. Its religious, totemic, and ceremonial significances provide another bypath, for primitive man in the most diverse times and places has consistently carved, painted, and adorned it with the symbols of his religious belief or has affixed to it the numerous "charms," "totems," and similar devices, which are presumed to insure success in the chase or in war. Upon Paleolithic examples from France certain incised "tally marks" are presumed to have indicated the number of victims of the spear thrower. In Australia, Eskimoland, and elsewhere a very natural phallic significance is often observable in its form and decoration. Mexican "atlatls," which have come from Mixtec, are so elaborately

carved, painted, inlaid, and gilded as to imply that they were not intended for actual or practical use.

After all, however, our own somewhat extensive research suggests that in basic construction and design there is no considerable difference in the spear thrower wherever it is found. The Australian implement is very like that of Boreal peoples, and specimens from Greenland are sometimes so similar to those of Tierra del Fuego, even to their thonged handles, that it would be difficult to tell them apart.

Since the discovery (1915-1916) by Moore of the unusual culture complex manifested at his Indian Knoll site on Green River, Kentucky, the problem of the "atlatl" has been brought into our own archeological field. Since then Fowke has investigated a similar site at the mouth of Town Creek in northwest Alabama; we have ourselves found a considerable occupation of the same group about the Falls of the Ohio. Webb has explored sites of similar character in the vicinity of Town Creek on the Tennessee River, and Webb and Haag have revisited the region of Green River, partially explored by Moore earlier. We have recited the various extensions to the Indian Knoll occupation in the chronologic order of their observance, which is after all unimportant.

Quite recently, Webb has concluded that certain hook-like objects of antler, customarily associated with rectangular or "reel shaped" so-called "bannerstones" of stone or bone in burials of this culture pattern, comprised, respectively, the distal ends of "atlatls" and weights attached to their shafts. Not only does he so conclude, but he appears likewise convinced that this discovery provides "a new common trait between this Indian Knoll culture pattern and that of Basket Maker II of the Southwest."

One of our own major problems has been, as has been true with others who have studied this manifestation, a determination of the use or purpose of these artifacts, an objective which is, in our opinion, still unaccomplished.

In an investigation of Basket Maker II sites in northeastern Arizona, Guernsey and Kidder recovered a number of "atlatls" of ancient Mexican type, also distributed through Central and South America and even in Florida. A feature of this "atlatl" form, as they reported, was the customary attachment of polished stone or chipped flint, fossils, seeds, or nuts to its shaft by ligature or wrapping of objects. The smallest of these objects reported was 1 inch in length; the largest, 2½ inches, weighing 2 ounces. In describing these objects, Guernsey states that, since no practical use could be imagined for them, he could think of them only as charms. The authority Krause classes similar objects attached to "atlatls" as "luck stones." In general, these objects of stone, bone, or flint are flattened upon the surface of attachment and range from ⅛ to ¾ inches in thickness. It is apparently largely upon the basis of the inclusion of objects of this character with the Mexican "atlatl" that Webb has drawn his conclusions and reconstructed a number of problematic implements incorporating the hook and bannerstone characteristic of the Indian Knoll culture pattern. In his report upon the Chiggerville (Kentucky) site he states that "these stones [of the Arizona sites] were securely attached to the throwing stick and

are designated 'weights' in the belief that they served to give balance to the instrument, and to increase its power in projecting the shaft when thrown." Referring to Guernsey's report, wherein two tabular "atlatl stones" or 2 and 2½ inches length, respectively, are illustrated, Webb includes as "atlatl" weights a much larger and heavier artifact found typically at Chiggerville and our own Ohio Falls sites. These artifacts, as they appear at Ohio Falls, are often 6 inches in length, and those figured by Webb are apparently of like size.

It is our own opinion, based upon evidence which we believe is substantial, that the movement of Indian Knoll peoples was southwestward and that the several occupational "stations" of the group extending from the Falls of the Ohio to northwest Alabama mark a progressive cultural decline. This is doubtless at variance with Webb's belief, as we interpret it, that the "atlatl" was introduced to Indian Knoll peoples by way of the region of Basket Maker II. Certain it is, in any case, that the Ohio Falls sites, embracing numerous related villages long occupied and densely populated, represent the most impressive concentration of this group so far observed. In addition, it is appropriate to point out that within this area the typical artifacts are superior in design and workmanship to those found elsewhere.

It was possible, at Ohio Falls, to account quite definitely for a successive occupation of the identical sites by a group of southern origin and a still later occupation by a second southern group considerably more advanced in culture. What happened to the original occupants of the site is, we suspect, involved with the appearance and removal of one or the other of these southern sojourners.

Although Moore makes no mention of it, it seems to us obvious that his Indian Knoll site includes, also, a secondary occupation. That this is patently true of Fowke's Town Creek site and those of Webb in the same region we feel certain.

In Moore's report upon Indian Knoll he submits the theory, upon which he was apparently not quite convinced, that the typical bone hook and accompanying bannerstones served respectively as crochet hooks and gauges or "spacers" used in conjunction in the fabrication of nets. Willoughby, whom Moore consulted, did not believe they were so used; nor did he believe that the hooks might have been the distal ends of "throwing sticks." Moore agrees with the latter conclusion and submits the following reasons for this assumption:

1. That the throwing stick or positive evidence of its use has not been found anywhere in the region in which is "The Indian Knoll."
2. That nearly all throwing sticks are of one piece, a construction that insures the required strength.
3. That small points of antler or of flint, which might have served as tips of the shafts used with "atlatls," were not found associated with his discoveries.
4. That some of his hooked implements were too crooked to have been used on throwing sticks and that the cavities in some were too inconsiderable to have served for the insertion of the main part of the "atlatl."
5. That the assumption that the hooked implements were parts

of "atlatls" offers no explanation in regard to the large objects of stone and antler found with the hooked implements and indubitably connected with them.

Concerning Moore's argument in general as it might apply to the Ohio Falls region with which we are most familiar, we have nothing controversial to offer except that at his own Indian Knoll site and at those of Fowke and Webb upon Tennessee River, crude hooked implements appear which might have served very practically as adjuncts of the spear thrower. In the region of Ohio Falls the hooks are consistently of a single pattern with delicately barbed ends which appear too fragile to have served as "atlatl" hooks and with their angular projections unfractured. It is true that leaf-shaped lanceheads of flint, these often 5 inches long, appear so abundantly as to suggest that the lance was used almost exclusively. So heavy were these points, however, that they must have been lashed directly to a shaft too heavy to have been propelled by the spear thrower. The bannerstones in this region are predominantly of polished stone, differing from those of Indian Knoll only, perhaps, in that many have concave ends and a few bear transverse ridges about their extremities. Those of bone are in this region most infrequent. There are here no round grave burials, there is no copper, there are no pipes, and it is probable that the few bits of pottery recovered pertain to a secondary occupation. Artifacts, including those of both stone and bone, are consistently carefully fabricated.

At Indian Knoll, on the other hand, copper appears. Round graves are typical, stone work (except in the case of bannerstones) is inferior, pipes are probably absent, and there is perhaps little pottery. Wyandotte hornstone, absent at Ohio Falls, probably supplies the bulk of material used in projectiles. The typical Ohio Falls lancehead is present but is in the way of being supplanted by notched or stemmed arrowpoints. As we have suggested, there is here a considerable diversity in the form and length of the bone hooks, many appearing too clumsy to serve as a competent implement for delicate textile work.

In connection with Indian Knoll, it is appropriate to introduce at this point a principal argument, or so we believe it to be, against the "atlatl" theory. This takes in the findings of Neumann upon an examination of the available skeletal material from Indian Knoll with which the typical bone hook and bannerstones were found associated. Out of a total of 31 burials reported by Moore with such association, the skeletal remains of only 17 were available for study. Of these Neumann found that: 4 represented adult males; 3 represented adult females; 4 represented adolescents; 6 represented children.

Of the remaining skeletons, one was reported by Moore as a child, leaving 13 adult subjects unaccounted for, some of which were doubtless females. The point to be considered is, of course, that it would be a reversal of aboriginal custom to include the weapons of a man, such as the "atlatl," so generally with burials of female and juvenile subjects. A similar situation prevailed at Ohio Falls, in that three bannerstones were found within the pelvic basin of a female subject, and these objects were likewise included with other female burials. At these sites, however, burials of children were confined to a separate quarter,

and neither of the objects in question was found in association with such burials.

As reported by Webb, Site Lu⁸⁶, many of the traits typical of Indian Knoll were found to persist in his northwest Alabama site, this quite near the Town Creek site of Fowke. He observes that there were here low, fully extended burials, 13 flexed burials, and 6 bundle burials. The typical lance point still appears; one "spear thrower of bone," only, is mentioned, but it is assumed that others made of wood had disappeared through decay. There were, however, no bannerstones, either of stone or bone, such as appear so abundantly at Indian Knoll and Ohio Falls. The suggestion that pointed bone fragments cut from the cannon bone of the deer, here quite numerous, served as projectile points, he believes is strengthened by finding many of them fractured and battered at the heavy end as if by impact. These objects, which appear both at Indian Knoll and Ohio Falls, are, we believe, typical of the Indian Knoll culture pattern, as well as are numerous other artifacts he describes from this site.

Of Fowke's Town Creek site, it may be said that the same pattern may be recognized, even if but feebly expressed. There are here numerous flint implements, mostly spearheads and knives, three short and eccentrically shaped bone hooks, bone awls similar to those found at the northern sites, and the projectile point of deer metapodial described by Webb. Here, however, as at Webb's nearby site, there are no bannerstones. At both of the Alabama sites the picture is one of a material culture at its lowest ebb. Fowke, in his customary fashion, asserts stoutly that there were numerous evidences of cannibalism manifest at the Alabama site he describes, and the proof he supplies seems to us sufficiently convincing.

In a paper whose reading is confined to ten minutes it is, of course, impossible to do more than faintly suggest the importance of pursuing the "atlatl" theory to its ultimate lair before the desirable, essential conclusions are submitted. For ourselves, we are yet in the situation of indecision. It does appear to us, however, that there are legitimate reasons for assuming that the assumption that the Indian Knoll hook and bannerstone are to be considered perforce as inseparable in function and purpose is erroneous. In detail we have examined, time and time again, authentic collections in museums here and there in which the veritable Indian Knoll bannerstone is recorded as from Massachusetts, New Jersey, Pennsylvania, Virginia, West Virginia, Ohio, Kentucky, Indiana, Missouri, Tennessee, Georgia, North Carolina, South Carolina, Florida, Oklahoma, and even from Michigan, Wisconsin, and Ontario. We have pursued it, at all events, as near the Mexican frontier as Oklahoma, but, unfortunately, it has led us also into Canada. Meanwhile, we have been unable to follow the antler hook beyond its restricted habitat within the boundaries of the region assigned to the pattern of Indian Knoll.

Report on Progress at Angel Mounds During 1939

GLENN A. BLACK, Indiana Historical Society

A preliminary report of progress during one of the several seasons required for the completion of a large archeological project must obviously be an inventory rather than a cultural synthesis. The Angel Mounds Site proving the rule rather than an exception, the following is a catalogue of pertinent data revealed by the first year's investigations.

Accurate surveying has substantiated early reports of features long ago erased from view by cultivation. Aerial photography has also contributed much toward a review of these features.

Excavation has proceeded successfully with gain counted by specimens and much data, equally valuable even if less tangible.

Ceramics, especially, point to an affinity with tribes living far to the south and southeast. Physical types, as represented in skeletal material, bear out the lead provided by pottery.

House sites, with remnants of the clay daub used for plastering the walls together and with fireplaces and small cache pits filled with maize, maize cobs, nuts, and seeds, provide an insight to a personal phase of aboriginal life in southern Indiana.

Charcoal found in the excavations has been recovered, treated, and stored with the hope that by dendrochronology it may be made to provide dates for occupancy of the village.

Although conclusions at this stage of the investigation are out of the question, it seems justifiable to state that Angel Mounds will be one of the most prolific village sites in the state; that the occupants carried with them a culture at least reminiscent of tribes in the south-east and Gulf States region; that the occupants were agricultural, highly sedentary, and animated by the accomplishments that go with permanency; that Angel Site was the center of government from which civil, economic, and religious decrees radiated to a community of sites, many of which have been found on the river terraces nearby.

Ethnological Notes on the Ottawa

PAUL WEER, Indiana Historical Society

Ottawa Indians, members of the Algonquian linguistic stock, were not overly interested in vacating their Michigan lands and moving onto reservations in Kansas as stipulated by treaties of the period 1830-1840. Fortunately, the white man did not insist; so for two hundred years and more the Ottawas have continued to inhabit the northwestern areas of Michigan's lower peninsula. In Emmet, Charlevoix, and Antrim counties, and trailing off into contiguous counties, these people have remained, in the midst of their incoming white neighbors, as fishermen and trappers, as small farmers, humble tradesmen, and as laborers in the lumber enterprises of this region. Since the lumber camps and saw mills and shipping docks of a generation ago have faded out with the final cutting down of the great pine forests, the Ottawa population has gradually dwindled. Middle Village, once the largest center of Ottawa life in the midst of numerous smaller habitation sites strung along the Lake Michigan shore in Emmet county, is now only a deserted village. The late generation is filtering out into new localities, but, here and there, notably at Cross Village and Harbor Springs, a semblance of village communal life is still to be found.

According to their own traditions, Indians in this territory must be "counted three layers deep," as they express it. First, long ago—they know not when—there were Indians here—they know not whom. Second, again there were Indians of whom the Ottawas remember nothing. Then, third, and last, came the Ottawas. That, they say, was about two hundred years ago, and then they had everything they have now in the way of living. They have always, they affirm, been poor farmers, made no pottery and only the most simple and crude stone, bone, and flint artifacts. They possessed no copper except that which an occasional individual carried as a charm made of that metal. Father Allouez saw a group of Ottawas blowing smoke into a bronze (?) image a foot high, an article which he recognized as an importation. Is it possible that most of the copper artifacts found on the surface in northern Michigan and Wisconsin (and the vast majority of these have been surface finds) were made after the coming of the French? Quoting from the Jesuit Relations: "Among the donnés and the Jesuit brothers were skillful workers in metal, who repaired guns and utensils of the natives, and taught them how best to obtain and reduce the ore from lead and copper deposits. We have evidence that the copper region of Lake Superior was at times resorted to by the lay followers and their Indian attendants to obtain material for crucifixes and for medals which the missionaries gave to converts" (1, 1:33-34).

The first recorded European contact with the Ottawas is credited to Champlain in 1615 when he met three hundred men of this tribe near the mouth of the French river on Georgian Bay (2, 2:167). These he called "*Cheueux relevez*," "men of the raised hair," because, to quote

two later sources from the Jesuit fathers, "their hair does not hang down, but is made to stand erect like a high crest" (1, 14:99, 41:77). Champlain reported that their weapons were the bow and arrow, a club, and shield of boiled leather; their bodies were much tattooed in many fashions and designs; their faces were painted in flaming colors; their noses were pierced; their ears were bordered with trinkets. The chief made Champlain understand that they had come to that place to dry huckleberries to be used in winter when nothing else was available (2, 2:168). Even to this day in the months of July and August the hills in these areas of northern Michigan and Ontario are covered with huckleberries.

In the following year Champlain's visit to some of their villages led to his observations that the Ottawa was a populous tribe and that their men were great warriors, hunters, and fishermen, governed by many chiefs, each ruling in his own district. He also observed that they were great tradesmen, sometimes traveling in pursuit of this vocation as far as 1200 to 1500 miles. He said that the women planted corn and other foodstuffs. The women had their bodies covered, but the men wore nothing except in winter when they usually threw a fur robe around their shoulders like a mantle. He committed himself to the effect that the women lived very well with their husbands (2, 2:168).

The shores of Georgian Bay and Manitoulin Island to the northwest are credited by early white contacts to have been the Ottawa country. Traditionally, the Ottawas, Chippewas, and Potawatomis were "three fires," which, in the most ancient days, were one—a single people dwelling around one great "fire" somewhere in the north, that is, in Canada. Furthermore, tradition states that the Ottawas and Potawatomis divided from the Chippewa at Mackinaw City. The earliest known habitat of the Potawatomi was in the present northeastern counties of Michigan's lower peninsula (2, 2:289). This suggests the possibility that, when first the Potawatomis and Ottawas left their Chippewa kinsmen, both groups, probably as one people, crossed the straits southward *via* Mackinac Island to the lower peninsula and that the group, later to be known as Potawatomis, chose the northeastern territory along the west shore of Lake Huron. The groups who became historically known as Ottawas took the northwest area around Big and Little Traverse Bays on the east shore of Lake Michigan before journeying to their historic seats as of 1615 *et seq.*

This thought is not apparent within itself but is now suggested, that is, that the Ottawas were resident in Michigan's northwestern lower peninsula before going east and north to their first historically observed seats around Georgian Bay and Manitoulin Island. Certain Ottawa legends which I heard last summer from one of the best informed members of this tribe confirm this¹ and, furthermore, suggest the probability that one of the lower "layers" here may have been their own ancestors.

When Champlain first met the Ottawas on Georgian Bay, he credited them with growing their own corn. But the Emmet county Ottawas of today have a tradition of journeying to Manitoulin from the lower

¹Joe Ettawageshik, Harbor Springs, Michigan.

peninsula and also retain a tribal legend of how first, in this same lower peninsula country, they were directed to use the gift of corn.

They say the Ottawas went to Manitoulin because a bad Midu caused them much trouble when they were living at Houghton Lake, which is about 100 miles south of Little Traverse Bay. This bad Midu stole an infant sunning in its cradle, but, because of a charm, no one knew for several days that the baby had been spirited away. When the time came that they were to know about it, the people heard a crying a long way off. Following the sound over to the west side of the lake, they heard the cry getting louder and louder; finally they came to a tunnel. They went into this tunnel and there were the baby's cries! But, as they went farther, the cries did not come any closer because the bad Midu was digging as fast as they were coming. Then the Ottawas went back to the opening of the tunnel and hung over it a virgin's dress so that the bad Midu could not come out that way. The leaders went around to the other side of the hill and tunneled in from there toward the crying and got the infant. But the people were still afraid for their children in that bad place; so they went eastward to the shore, near the place Port Huron is now located, and from there went to Manitoulin and spread over their new lands. All of this vast territory northwest of the Huron lands was first called by the French the country of the Ottawas; the first Jesuit mission founded in all that country at Sault Ste. Marie in 1641 was called the Ottawa Mission.

The tale of the gift of corn is as follows: One fall the Ottawas departed from Wequadonzing, Little Harbor, to go south into warmer lands to hunt. They kept going until they came to Sleeping Bear, which is a high hill near the present city of Frankfort, approximately 120 miles south of Little Traverse Bay. After camp had been made for the night and everyone was resting, the young hunters heard a scratching noise on the hill. Thinking it the sound of enemies, they went up there but could find nothing that might have made the noise. When everyone was again resting in camp, the scratching noise came down as before; once more the young men went towards the sound but saw nothing except some little stalks waving in the breeze. Again they went back to their sleeping, and again they heard a scratching. For the third time they went in search of the makers of the noise, and, very carefully coming toward the sound, they discovered it was the little stalks scratching their sides for them to hear. The young warriors pulled these up and returned with them to the Sagima, the medicine man. Next night the Sagima had a dream, and on the following day, when the warriors, hunters, and all who were following with them had assembled, he said that these little stalks that had called to them were saying "mindamin," corn. From these he kept the seeds, which were all put in the ground the next year; these grew more "mindamin" which was then divided among all the Ottawa families, some to be saved for growing but the most part to be used for their eating. And so, the legend says the Ottawas had corn before they went to Manitoulin.

The Jesuit Relations of 1662-1664 recounting Father René Menard's labors among the Ottawa, says: "corn and bread are entirely unknown in those countries" (1, 48:119). And in the same narrative: "In this

country there is wild rice" (1, 48:123). This does not mean that corn was then unknown to the Ottawas, for it refers to a time when they and their neighbors, the Hurons, having been driven out of their lands in the proximity of Georgian Bay and Manitoulin Island by the Iroquois, were dwelling in northern Wisconsin, a native habitat for wild rice. Here, evidently, life had become too complicated to include corn planting! In the year 1665 Father Allouez founded his mission for them at La Pointe, on Chequamegon Bay, on the south shore of Lake Superior. Father Marquette succeeded Allouez at La Pointe in 1669. Shortly thereafter the Ottawas and Hurons incurred the hostility of the Sioux, who drove them eastward like so many leaves before an autumn blast. Marquette followed and founded a mission at St. Ignace, which became the largest and most successful mission in the northwest. Here in 1673, just before Marquette started on his famous voyage leading to his discovery of the Mississippi river, were gathered 1300 Ottawas and 500 Hurons. During the following 50 years the Ottawas were *ex patria*, wandering in small groups here and there, some as far south as Detroit and Fort Wayne, others going equally far south on the other side of Michigan and into northeastern Illinois. By 1730 many had returned and once more were living around Big and Little Traverse Bays where they have remained to this day.

The Ottawas say that in this country they had wild potatoes, wild wheat, wild rice, wild turnips, but no wild corn. This last item was something different that grew only in planted fields where they put it. They have no traditions concerning first knowledge of tobacco. Here is an interesting definition for the word Kenekinic which I am repeating just as it was given to me: "Men are sitting around in a circle, not in solemn council, but just enjoying themselves. In the center is a wooden dish filled with tobacco. Kenekinic means—you reach in and help yourself to some tobacco."

The Ottawas claim that their people were not pottery makers. They had this ingenious method for boiling meats without pot: A deer "gut" was cleaned out and filled with water; pieces of meat were put in this, and the "gut" placed by the side of the fire. By the time the "gut" was burned the meat was cooked, or cooked enough.¹

Mink bones were used for sewing needles. Strange to say, in this birch country, birch bark was not used for canoes by the Ottawas. Dug-outs were their chief mode of water transportation, but, when they were traveling on land and came to a body of water that required a boat, they made what they called "temporary canoes" from elm bark. To quote, "When they got to the other side they just left the boat there." This use of large boats fits in with the historic knowledge that the Ottawas were great traders and, perforce, great travelers. They led all the early expeditions down to Montreal to trade with the French, and, after the first contact years, they continued to act as middle-men. The Ottawas claimed the great river as their own to the French, and no others might travel without their consent (2, 2:168). Father Allouez said that, regardless of their nationality, all the early Indian voyagers

¹Joe Ettawageshik, Harbor Springs, Michigan.

²Fred Ettawageshik, Harbor Springs, Michigan.

down to Montreal called themselves Ottawas, under whose convoyance the trips were made (2, 2:168).

The Ottawas had a system of patrilineal, exogamous gens. The Ettawegeshiks say their family is called "kewawegwame," the underground or earthen-house people, and they explain this thus: Long ago the Ottawas went into the west to war on enemies. Among the prisoners they brought back a young brave who out there had lived in an earthen house. This foreigner was a great warrior and was permitted to marry into the Ottawa tribe, and for many generations, even to today, his descendants are known as the underground or earthen-house family.

The Ottawas say their language is almost the same as the Chippewa but not mutually intelligible. One must spend a little time in the Chippewa villages, and then the difference disappears. As explained to me, Ottawa is low Chippewa, the former employing a "K" sound where Chippewa uses a "C." The Jesuits in their zeal made a tactical error in baptising the Indians' dying, aged, and infants. This paradox made the new religion a highly questionable venture to strong, vigorous Ottawas in the prime of their pristine faculties, but today they are all devoted Catholics, and most of their children attend parochial schools.

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Culture Parallels to the Delaware Walam Olum

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Recent analysis of the mortuary customs of the Shawnee and other eastern North American tribes served to illustrate the fact that very few traits are likely to be found unique to a single tribe within a given culture area. From a total of several hundred Shawnee burial traits, only 14 traits could be isolated as diagnostic or unique to the Shawnee alone. Moreover, six of these 14 traits occurred in slightly recast form or entirely apart from burial customs in the cultures of eastern North American tribes other than the Shawnee (1).

The uniqueness of the Shawnee burial complex or, I dare say, any other large Shawnee complex lies not in its having an impressive total of traits which are peculiar to this one tribe alone but rather in the fact that the complex as a whole follows a pattern which is distinctive for this tribe.

This fact, that the cultures of various groups within a relatively homogeneous region are apt to show few original traits and are chiefly distinguishable one from the other on the basis of selection and arrangement of elements which have a wider distribution, has received attention from several present-day anthropologists. In a recent noteworthy study Spier (2) has shown that the Ghost Dance, which caused such disturbances among certain Plains tribes at the end of the nineteenth century, was not, as Mooney had held, a new cultural phenomenon developed by the Paviotso to answer spiritual needs of the moment. Rather, the ultimate origin of the Ghost Dance lay in a much older dance form which paralleled the Ghost Dance, for which Spier has coined the name Prophet Dance. This earlier dance form which preceded the Ghost Dance "was known to all the tribes of the northwestern interior, without exception, from the Babine and Sekani on the north to the Paviotso of western Nevada far to the south." In post-white times the Prophet Dance was the source not only of the Ghost Dances of 1870 and 1890 but of several other religious movements among Plateau tribes.

Du Bois (3), working concurrently but independently of Spier on the Feather cult, one of the other religious movements which sprang from the Prophet Dance, also arrived at the conclusion that the Feather cult of the Middle Columbia River tribes was largely derivative of older practices. In her study Du Bois says, "The striking characteristic of the Feather cult was its lack of originality. With the exception of spinning [whirling] and vomiting in the initiation rites, every feature can be traced to some definite and prior source." Ray (4), in a review of Du Bois' study, points out that even the two traits Du Bois mentions are "of doubtful originality" in the Middle Columbia region. "Vomiting is found... as a ritual and curative practice. The whirling is easily associated with the traditional winter dance demonstrations of... persons with whirlwind as a guardian spirit."

What holds for particular complexes also holds true for the culture

of a group as a whole. Webb (5), in searching for distinctive Cherokee traits, found that "it is not easy to determine what traits are definitely diagnostic of Cherokee material culture" since so many traits attributable to the Cherokee have distributions far beyond this particular group. Likewise, in my own study of the comparatively simple culture of the Tübatulabal, a California group, I was able to isolate only three features of Tübatulabal culture which seemed unique to that group alone (6). Since the study was made, one of these three traits has been found among the Kawaiisu (7), southern neighbors of the Tübatulabal, and it seems not only possible, but probable, that the other two features will also eventually be recorded among some of the Great Basin or California groups.

At first glance, the Delaware Walam Olum appears to be a cultural complex unique to a single eastern North American tribe and lacking in antecedents among the Delaware or any other eastern group. As such, we would have valid grounds for questioning its authenticity as a native production. Is its uniqueness, however, due to the fact that no parallels can be found for the various elements or traits which enter into the Walam Olum or rather to the fact that certain elements, common to several Eastern Woodlands groups, occur in unique juxtaposition in the Delaware document?

If we analyze the Walum Olum in respect to its major elements, we find that the production as a whole is the sum of several items, as follows:

1. Pictographs—painted on sticks, used as mnemonic devices, for songs, songs esoteric (?);
2. Primeval water—deluge motives;
3. Genealogy of chiefs—wanderings of bands under chiefs.

Our problem is to see whether any or several of the above traits can be found among eastern North American tribes other than the Delaware. Regarding the first point in the analysis, the use of pictographs, Schoolcraft (8, p. 32) notes in *Oneóta* that pictographs were used by the Menomini, the Winnebago, the Potawatomi, the Chippewa, and the Ottawa, as well as among the Dakota and Plains tribes to the west and south. Pictographs painted on sticks or tablets of hard wood, in contrast to pictographs painted on birch bark or buffalo skins, have a more restricted distribution; to date we have found specific mention of such only among the Chippewa, Kickapoo, and Delaware. The use of such tablets or sticks for remembering songs, especially songs of a religious or esoteric nature, is found not only among the Delaware but also among the Chippewa and Kickapoo. The manner in which the Chippewa used engraved wooden mnemonic tablets is described in some detail by Kohl (9) and Schoolcraft (8, pp. 27-35); I wish here only to mention certain interesting facts concerning the presence of engraved and painted sticks among the Delaware and Kickapoo.

The use of prayer sticks engraved with mnemonic symbols is first noted for the Delaware ca. 1762. At this date a prophet appeared among the Delaware. This prophet, according to Pontiac, the Ottawa chief, had talked with the Great Spirit, received instructions from the divinity concerning the course of life the Delaware should follow, and then had

been given "a prayer, embodying the substance of all that [the Prophet] had heard. . . . [This prayer] was cut in hieroglyphics upon a wooden stick, after the custom of his [the Prophet's] people; and he was directed to send copies of it to all the Indian villages" (10).

Painted sticks graven with "hieroglyphic" or mnemonic characters were also carved by the Kickapoo prophet, Kanakuk, and sold to his followers around 1827-34 (11). None of the Delaware Prophet's prayer sticks seem to have been preserved, but at least one of the Kickapoo prophet's has found its way into the U. S. National Museum, as a gift from Mr. C. H. Bartlett of South Bend, Indiana; Mr. Bartlett obtained the stick from a Methodist missionary of Mill Creek, Indiana (12, pp. 641-1110). This prayer stick tallies with descriptions of Kickapoo prayer sticks given by Catlin (11, pp. 136-137), being made of maple, a little more than 12 inches long, 2 and 9/16 inches wide, and 3/4 of an inch thick. Originally, it was painted a bright red on one side and green on the other. One side is smooth, the other carved with mnemonic figures, many of which "bear some resemblance to the old black-letter type of a missal," and there are traces of Catholic influence in the manner in which the characters are grouped together (12, 698-699). When using the stick, the right index finger was put first under the upper character while repeating the short prayer which it suggested, then under the next, and the next character, and so on to the bottom, the whole prayer being sung as a sort of chant (11, p. 137).

Turning to our second major point, the primeval water-deluge motives which comprise Songs I and II of the Walam Olum, we know that these motives are widespread in eastern North America and also occur in other parts of the continent (13). The version of the deluge myth given in the Walum Olum parallels in structure and in many details versions found among tribes neighboring to the Delaware, such as the Shawnee.

Parallels for our third point are not so easily found among the tribes of eastern North America and will require further research before documented proof that long genealogies of chiefs were preserved in this area. Any references bearing on this point would be extremely valuable; with the aid of mnemonic devices, it does not seem improbable that genealogies of chiefs could have been kept with comparative ease.

At this point in our investigation of culture parallels to the Walam Olum, it does not appear that the document is so aberrant as to be open to suspicion regarding its authenticity as a native production. Rather, distributional evidence seems to show that many of its elements were not limited to the Delaware alone but were fairly widely distributed among Eastern Woodlands tribes. The combination of these elements in the Walum Olum is, so far as we know now, unique to the Delaware. However, this is as we would expect and is consonant with conclusions reached from studies of other cultural complexes to which references were made in the first part of this paper.

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Remarks Regarding the Pictographs of the Walum Olum

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As you know, the *Walum Olum* was the mythological and historic record of the Lenape Indians obtained by Rafinesque in the early eighteen hundreds. It consisted of a series of sticks, painted with red pictographs serving to remind the Lenape of the wording of the songs describing their tribal history.

The outstanding authority on the *Walum Olum*, Dr. Daniel G. Brinton, says on page 161 of his great book, *The Lenape and Their Legends*: "There is generally a distinct, obvious connection between the symbol and the sense of the text sufficient to recall the latter to one who has made himself thoroughly familiar with it." Careful study and observation soon bring out the fact that there are certain symbols which recur as the matter in the text recurs, and it may be of interest to mention a few of the more obvious.

Certain incongruities and differences between the text and the symbols in Brinton's book suggested that a careful comparison should be made between the Rafinesque figures in a photostatic copy of his notebooks and the Brinton pictographs. Fifty-eight mistakes in the Brinton symbols were found, many of them no doubt due to the carelessness of the printer and to the injury of plates during the printing process. This leads to a suggestion that there may be differences between Rafinesque's figures and those of the *Walum Olum* itself, which, sad to state, have disappeared.

There are, of course, certain very obvious meanings where crude drawings are made of the objects mentioned, such as birds, canoes, human figures, the moon, the beaver, spruce and sassafras trees, and the well-known sun symbol.

The human figure is often depicted by the usual vertical oval body with a small circle for the head and straight lines for the legs. In one instance, conversation is indicated by a line drawn between the heads of two figures. Walking or a journey is pictured by the legs being drawn far apart as in the act of walking.

As might be expected, in twenty cases the East is shown as being at the right side of the drawing; North, above the base line or toward the top of the figure in five places; South, below the line in eleven drawings; and West, the left in four instances.

Death or absence is suggested in three figures by the symbol of the object being drawn below the base line.

The various tribes are depicted by several styles of head-dress on the small pictographs of the human figure. For instance, two lines, looking like snake fangs rising from the top of the head, represent the Snake Indians in eleven examples, reptiles in ten cases, and merely evil in fifteen places.

The Lenape Indians are usually pictured by one straight line rising diagonally to the right from the top of the head; sometimes, however,

there are three lines, one vertical and one rising diagonally on each side. Occasionally there is no head-dress at all. A chief generally is shown by the same number of larger and more decorated lines. The Ottawa sign is a short vertical mark and a curved line swinging off to the right from the top of the head; the Talligewi, a straight horizontal line drawn to the right from the middle of the top of the head; and the Talmations—Huron, Iroquois, or Wyandots—a horizontal mark across the top of the head with a vertical line running up from the center of it. Northerners are suggested by a vertical line from the head with a horizontal stroke across the top of it. The symbol of the white man is a circle or a square with a dot in the center with a cross rising from the top.

In five cases, the pictograph for food is a group of small circles or a single small circle, probably representing corn.

Eight times, houses or villages are suggested by parallelograms or a group of parallelograms; in ten instances, such groups of parallelograms seem to tell of favorable circumstances and perhaps indicate many houses.

Land or islands are depicted by several modifications of a semi-circle resting on a flat base line.

Nineteen times, the symbol of immortality or divinity is the usual circle with a dot in the center.

Each river has its own symbol, such as the Yellow River, the Fish River, the White River (the Wabash, according to Rafinesque), and the Straight River.

War, fights, battles, enmity, or hatred are shown in twenty-one instances as diagonal crosses.

Bodies of water are pictured by inverted semicircles with a horizontal line showing the level of the water.

Ice is symbolized by the same figure with a double horizontal line.

Extreme cold or snow is shown as an inverted semicircle below which is suspended small tangential lines, possibly representing the aurora or a snowfall.

In four instances, the eastern seashore is indicated by two figures which are easily understood.

Single or double connecting lines seem to show love, relationship, or friendship in ten cases.

An isosceles triangle is the glyph standing for chieftainship in nine instances; in five earlier pictographs, it seems to mean rather the headquarters of the tribe, which is, after all, a related idea.

Doubtless, a thorough study of this subject would reveal many relationships between the pictographs and the subject matter, and the above superficial report should pique our interest and lead to an exhaustive study of this feature of the famous Hoosier Odyssey—the *Walum Olum*.

The Lenape and Munsee Dialects of Delaware, an Algonquian Language¹

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Over thirty years ago, in an extensive comparative study of Algonquian languages, Michelson found that information on the Delaware language as given by Zeisberger was "not good." The weakness which concerns us is that "The forms of the various dialects are given without assigning each form to its proper dialect. . . (1, p. 275)." Michelson supposes that the three Delaware divisions, Munsee, Unami, and Unalactigo, were separate tribes but, nevertheless, spoke mutually intelligible dialects. As a result of some field experience with the Munsee of Kansas and the Delaware of Oklahoma, Michelson revised his conjectures of resemblances between Delaware and other Algonquian languages but did not compare Delaware dialects as such (1, p. 290a).

We have, as the basis for the present study, two sources. The first is an important manuscript of lexical materials, recorded by Dr. Frank Siebert, who says, "My Munsee material was collected from Nicodemus Peters in June, 1938 (aged 77), at Smoothtown, Six Nations' Reserve, Ontario. However, some of that material was collected at the same place in September, 1931, and later revised in 1938. My informant in 1931 was Nicholas Powless (2)." Since both informants mentioned are now dead and since the remaining Munsee speakers of Smoothtown have only a partial command of their native language, it is quite possible that much of this material is now irreplaceable.

The second source is my own field notes of Delaware as spoken by Willie Longbone of Dewey, Oklahoma. The Oklahoma dialect represented is known locally as Lenape.¹

Neither Dr. Siebert nor I regard our records to be in final phonetic form. Phonetic explanations are made as special problems in orthography arise.² The Munsee forms are cited as M., the Lenape forms as L.

1. Initial *wa-* and postvocalic *-wa-* in Munsee appears in Lenape as *o*. M. *wak*, L. *o:k* 'and' (the colon after vowels marks vocalic length); M. *wa:sLew*, L. *ó:sële:w* 'light' (capital L marks a voiceless L); M. *ěwa:n*, L. *aón* 'fog'; M. *pa:wá:law* 'guardian spirit', L. *mpaó:la* 'my guardian spirit'; M. *e:Mhěwá:něs*, L. *e:mhó:něs* 'spoon'. Possibly instances like M. *chihxa:ma:kan*, L. *chi:xamó:kkan* 'comb' imply an underlying **-ěwa:-* for the Munsee *-a:-* which corresponds to the Lenape *-o:-* (doubled consonants, as *-kk-*, are written for a single long phoneme). Instances of Munsee *-wa-* after the consonant *-k-* also appear in Lenape as *-o-*. M. *těk"a:x*, L. *tahkóx* 'turtle'; M. *ěpi:k"an*, L. *ahpi:kkan* 'flute';

¹Field funds for work in Oklahoma were administered by DePauw University; work with informant at Ann Arbor was sponsored by the Linguistic Institute of the University of Michigan.

²In place of special phonetic characters, *ə* is used for the schwa symbol (turned *e*), and when no other stress is marked in a given Lenape word, the stress falls on this vowel; *sh* is used for the *s*-wedge symbol (aspirant English 'ship'); *ch* is used for the *o*-wedge (an affricate as in English 'church').

M. takwáppo 'he is married', *L. ntakohpu:ha:lkéhena* 'I married her'. In these correspondences, Munsee appears to be the more archaic dialect.

2. However, in preserving *-we:-* and *-wi:-* after *-m-* and *-k-*, Lenape is the more archaic, for in these sequences correspondences show Munsee *-o:-*. *L. kwénaskwé:e:*, *M. k"ēna:skó:teu* 'high weeds'; *L. eha:pchalá:mwi:s*, *M. a:pēchá:li:mo:sh* 'diving duck'; *L. mwe:kkané:yok*, *M. mo:kēne:wak* 'dogs' (*L.* develops *-y-* between *-e:-* and *-o-*; the *-o-* is from *-wa-*, as 1, above).

3. Some Munsee forms with *w* and *wa-* before consonant correspond to Lenape forms without the preceding *w*, *wē-*, which leaves its trace in *-o-* instead of *-a-* after the consonant. Both metathesis of preconsonantic *-w-*, and contraction of *wa-* to *-o-* (see 1, above) are productive features of Lenape phonology. *M. wahapp'e*, *L. shóhpe* shore; *wēla:kan*, *L. ló:kke:ns* 'wooden bowl' (*-n-* before *-s-* or *-sh-* in Lenape nasalizes the preceding vowel); *M. wēla:kēna:ho:Nshi*, *L. lo:kkahanú:nshi* 'elm'.

4. A "floating" *-h-* sometimes appears after a vowel in Munsee, but before the corresponding vowel, either in postconsonantic or word-initial position in Lenape. *M. ahpi:s*, *L. hápi:s* 'tumpline'; *M. ohpēn*, *L. hópēni:s* 'potato'; *M. wcháppihk* 'medicine', *L. chēphik* 'root'; *M. mohk*, *L. mhúkw* 'blood'; *M. wa:hpán*, *L. hópan* 'lung' (cp. also 1, above). Less regular instances of "floating" *-h-* are *M. ma:kahkw*, *L. mahká:kw* 'leech'; *M. wihsēkhi:m*, *L. wisahki:m* 'grape'.

5. Quite frequently Lenape has a plain stop (less frequently a long stop) where Munsee shows a preaspirated stop. *L. mé:chi*, *M. mehchi* 'now'; *L. tú:pan*, *M. tohpan* 'frost'; *L. ke:tanēttú:wi:t*, *M. keht:nētto:wi:t* 'god'; *L. nu:wú:ttam* 'I have good sense', *M. nēwewáhtam* 'I know' beside *M. nēwewihtam* 'I am wise'; *L. tēwé:kw*, *M. tēwehkw* 'lizard' (preaspirated stops never occur in word-final clusters in Lenape; but cp. *L. tēwé:kkok* 'lizards'; *L. wēlakshia*, *M. wēlákshi* 'guts' (the cluster *-hks-* is not permissible in Lenape; but cp. the relative form, when the cluster is interrupted by the *-ē-* vowel: *L. nu:lahkēshia* 'my guts'). The reverse is also found: Lenape shows preaspiration lacking in Munsee. Incidental examples of this can be found under 1, above. Preaspiration is phonetically clear; impressionistic errors are less probable here than in recording other sound types in Delaware dialects.

6. Munsee retains a word-initial vowel lacking in a few Lenape words, *M. ózk"ew*, *L. xkwe:w* 'women'; *M. a:sēná:mēNshi*, *L. sēna:mē:nshi* 'sugar maple'; *M. ēsk"onde*, *L. skóntay* 'doorway' (the use of *-d-*, *-t-* is merely a matter of orthography: in both dialects, the dental stop after *-n-* is voiced). In one instance Lenape retains the initial vowel lacking in Munsee: *L. a:na:kkēme:s*, *M. shi:xi:kímēNahi* 'red maple', but this comparison presents other difficulties also.

7. The *-ē-* vowel recorded between consonants in some Lenape words does not appear in the Munsee record. This may reflect a different phonetic interpretation of the phonetic facts. Or it may indicate that Munsee has actually travelled further along the road to developing new clusters. Munsee *-l-* as the second member of such clusters is *L.* while the corresponding *-l-* in Lenape is fully voiced. *L. kēla:hí:kkān*, *M. kLa:hí:kēn* 'trap'; *L. sú:kkēla:n*, *M. so:kLa:n* 'it is raining'; *L. pēlé:ni:kw*, *M. pLe:n* 'flying squirrel'; *L. we:mahté:kkēni:s*, *M.*

we:mētēkni:s 'dwarf'. An instance or two is found in which Lenape develops a consonant cluster interrupted in Munsee by a -ē- vowel (see example under 2, above).

8. Some Munsee words in *mē-*, *m-*, and *n-* appear in Lenape without the initial nasal. M. *mēsi:m*, L. *si:mi:n* 'hickory nut' beside L. *shi:mē:nshi* 'hickory nut tree'. Some pairs show also the "floating" -h- which appears after a given vowel in Munsee, before the vowel in Lenape (see 4, above): M. *mihLóhsēs*, L. *hilú:sēs* 'old man'; M. *mihtēk* 'tree' with *mihtēkwak* 'trees' and L. *hittukw* 'tree', *hitku:k* 'trees'; M. *ptēkkwi:mēNshi* (underlying M. **mtēkkwi:mēNshi*), L. *tēkkwi:mē:nshi* 'walnut tree'; M. *n(ē)gwētēn*, L. *kwētēn* 'once'.

9. Lenape appears to tolerate word-final -kw in some instances where Munsee reduces -kw to -k. L. *shēkw*, M. *shēk* 'but'; L. *mi:xá:kkana:kw*, M. *mi:xá:kēnak* 'white ash tree' (but with plural suffix, the M. form still lacks postconsonantic -w, while the L. form shows the regular change from -wa- to -o-: L. *mi:xá:kkana:kok*, M. *mi:xá:kēnakal* 'white ash trees'); L. *mhukw*, M. *mohk* 'blood'. But -kw is found in word-final in Munsee (see 4, above). The sequence *xwa-* in Munsee appears in Lenape as *xa-* where one would expect to find *xo-* (according to 1, above): M. *xwa:sk"i:m*, L. *xáskwi:m* 'corn'.

10. The class of Lenape inanimate nouns in -ay is irregular in having beside singular -ay an underlying -e:w- which yields -e:(y)o before the plural suffix -a (by regular phonology). The corresponding nouns in Munsee do not undergo either the irregular development of a special singular form in -ay, nor the regular phonology of deriving -o- from -wa-; furthermore the plural suffix in Munsee appears in the full form -al. Compare L. *kwshá:tay* with plural *kwsha:té:yo*, and M. *kwsha:tew* with plural *kwsha:te:wál* 'smoke'. See also the example under 6, above.

11. Some animate noun endings appear in reduced form in Lenape, in full form in Munsee. Thus L. *alánkw* with plural *alánkok*, and M. *ēla:nk"ew* with plural *ēla:nk"ewak* 'star'.

12. The glottalized stop is a specialized development in the Munsee dialect. Michelson reported that every stop might be glottalized, but did not assign this development to any specific dialect (1, p. 290a). Our examples show two cases of glottalized *p* in Munsee which correspond to *p* in Lenape. M. *wshayp'e*, L. *shóhpe* 'shore'; M. *shwēpp'i*, L. *shuwánpí* 'salt water'.

13. In general, vowels of the two dialects are the same. An occasional vowel of one dialect may be reduced to a -ē- vowel in the other (see 11, above), possibly as a result of fast speech. In the following example, Lenape -ē- is probably phonemically -ē-; it is, at least, subject to the regular syncope of -ē- in syllabic-final before suffix: L. *pu:pú:kkwēsh* with plural *pu:pú:kwshak*, and *popokwi:s* 'oriole'.

14. Lenape -u-, -u:- is recorded where Munsee shows -o-, -o:-. This fact is perhaps not unrelated to the derivation of some Lenape -o-, -o:- from -wa-, -wa:-, a development which is not shared by Munsee. If such derivation, with analogical extension, will account for the origin of Lenape, -o-, -o:-, then Lenape -u-, -u:- can really be said to be identical with Munsee -o-, -o:-. The difference between Lenape -u- and Munsee -o-

is orthographic, not phonemic. Phonemically then, Munsee has only one high back vowel, -o-, while Lenape has the same vowel which in our orthography is written -u-, and in addition Lenape has a second high back vowel, -o-, not to be confused with Munsee -o-. L. *yúkwe*, M. *yo:kwe* 'now'; L. *kwēnēmuxkw*, M. *kʷēnēmoxkʷ* 'otter'; L. *mēnú:tte:s*, M. *mēnó:te:s* 'pouch'; L. *ká:kku:n*, M. *ka:kon* 'leggings'; L. *mēkú:s*, M. *mēko:s* 'awl'; L. *wiyú:s*, M. *wēyó:s* 'meat'; L. *mu:s*, M. *mo:s* 'elk'; L. *hu:s*, M. *hohs* 'kettle'; L. *ku:n*, M. *ko:n* 'snow'; L. *ki:shu:x*, M. *ki:shox* 'sun'.

15. Many words in the two dialects are identical, if we discount orthography and count only the phonemic facts (see 14). Additional examples may be cited at random: *wte:* 'heart'; *ke:kw* 'wampum'; *wi:ninkwēs* 'mink'; *énta* 'there'; *é:li* 'because'.

16. Words which are otherwise identical in the two dialects may differ in inflectional endings. Thus, the inanimate plural suffix appears as -al in Munsee, but without the -l, as -a, in Lenape. Both dialects give *mi:n* 'huckleberry', but M. *mi:nal*, L. *mi:na* 'huckleberries'. Both dialects give *wi:na:kw* 'sassafras tree', but the gender of this word, as marked by plural suffixes, appears to be animate in Lenape, inanimate in Munsee: L. *wi:na:kok*, M. *wi:na:kwal* 'sassafras trees'. Both dialects give *ménkwew* 'Seneca', and the animate plural suffix for both dialects is -ak, but in suffixation the sequence of phonemes is preserved only in Munsee; in Lenape it is phonologically contracted (see 1, above): M. *menkwé:wak*, L. *menkwé:yok* 'Senecas'. Beside the participle suffix -t, there is an agentive suffix -s. This may be reflected in the correspondence of nouns in -s and in -t. L. *hémpe:s*, M. *he:mbét* 'shirt'.

17. Some instances of partial similarities may be classified. Compound words may have one stem identical in the two dialects, the other not. M. *émangēme:kw*, L. *xinkome:kw* '[one] big fish'; cp. L. *amankamé:kkok* '[many] big fish'. A stem which appears freely in initial position in one dialect may be restricted to non-initial position in the other dialect. M. *tolpew* 'turtle', L. *pi:selatú:lpew* 'soft shell turtle'. Both dialects give *lénu* 'man', and in the non-initial by-form both dialects show syncope of the -ē- vowel, but in Munsee a consonant cluster results while in Lenape the neighboring consonants contract to a single long phoneme. M. *lepewe:wi:lno*, L. *lepwe:innu* 'sage, wise man'; M. *ma:nétwi:lno*, L. *manéttu:winnu* 'shaman, spirit man'. Specialized meaning may result in one dialect, not in the other. M. *mohkētonēs* 'salamander', L. *mhukwtú:ne:* 'he has a bloody mouth'. Both dialects give *manéttu* 'spirit'; Lenape, but not Munsee, has developed a non-initial by-form. L. *mahtánTu*, M. *me:tsi:t manétto* 'no good spirit, devil'. Analysis of partial similarity is far from easy: L. *xe:s*, M. *xay* 'hide'; L. *ae:sēs*, M. *ēwe:yēyēs* 'animal'; L. *kwi:ppēlēnay*, M. *ēkʷi:pIa:wēn* 'hoe'; L. *maná:tay*, M. *mēna:hēn* 'island'; L. *panahpe:kw*, M. *shpáNshpex* 'muskmelon'; L. *chi:skúkkus*, M. *ki:shko:sh* 'robin'.

18. Instances of complete lexical dissimilarity between the dialects are relatively infrequent.

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Birch Bark Records Among the Chippewa

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Picture writing was a trait with a wide distribution among the North American Indians. Among the Algonquian speaking tribes there were few, if any, breaks in the distribution of the practice. The techniques used were principally line drawings in ashes or sand, charcoal on blazed surfaces of trees, paints on leather, and incisions on pieces of bark, wood, or rock.

Examples of picture writing that may be definitely attributed to the Chippewa are fairly common, principally because of their residence in the growing range of the birch tree. The bark of this tree served them for many purposes—to cover their dwellings, to make containers and utensils of various sorts, to build canoes, and to carry records. The drawings in sand or ashes and on trees were not very permanent, and the drawings or paintings on rock, while permanent, were not portable and hence did not remain in the possession of the maker or his heirs. Birch bark, however, was not only obtained but worked and preserved with ease. Wooden tablets possessed the same attributes of permanence and portability, but they are not as numerous as the birch bark rolls, probably because they required more exertion and skill in manufacture. The only differences between the wooden tablets and the birch bark rolls, aside from the material, are the greater use of color and the generally better workmanship in the tablets. The one difference is explained by the fact that birch bark does not take color readily. On the other point it must be added that some of the figures on birch bark were equal or superior in artistry to those on the wooden tablets.

The purpose of an individual record determined the type of symbols used, the size of the record, and perhaps also the excellence of the delineation. The drawings were of two general types on the basis of the subject matter: first, those in which the subject matter was understood only by instructed persons, and, second, those intended to be understood by the general public. The second type included totem marks, names of persons, messages left by travellers, records of time, *et cetera*. The first type consisted principally of the records and songs of the Midewiwin, other songs, records of dreams and drawings used as charms.

The figures used in the records of the public type were mainly descriptive in character and possibly also related to the sign language of the Indians as maintained by Rafinesque (1). The figures used in the records of the Midewiwin were ideographic, esoteric, and mnemonic although they may have had their origin in the sign language, that is, they suggested an idea to a person who had had the proper instruction and served to recall definite words which were not indicated in the drawing. Not only was instruction as to the meaning of each figure required but also information on which was the initial figure and the direction of reading in each record. The Chippewa never

standardized the direction of their writing, and, consequently, one roll will read from left to right, another from right to left; others progressed clockwise or counter-clockwise around the edge of a piece of bark, and some of several rows of figures had alternate rows read in opposite directions.

The bark pieces varied in size from a few square inches for a charm drawing to a roll three or four feet in width and fifteen feet or so in length for a chart showing the origin or the degrees of the Midewiwin.

The excellence of the drawing on different bark records varied with the purpose and the skill of the artist. Some were very crude and some were very carefully executed. A birch bark conveying a message of only temporary importance would not have the care lavished on it that might be bestowed upon the record of a band's migration or its success in war which might be cherished for several generations. The same difference in execution is found in the birch bark records relating to the Midewiwin as in the records of the public type. Ordinarily, the records of songs were made by each individual to remind him of the exact words and order of the songs as he learned them. These were his personal possessions and were either buried with him or burned after his decease. The pictographs were often hastily sketched as pictographic excellence was subordinate to a grasp of the meaning of the song and its exact words. On the other hand, the birch bark rolls showing the origin of the Midewiwin, the charts of the different degrees, and the movements in each ceremony were used in instruction, shown to the assembled initiates, and were expected to be handed down from generation to generation. Naturally, these usually show much more care in their manufacture than the song records of individuals.

The first birch bark writings mentioned by the early explorers were messages left by travellers on their abandonment of campsites. Other messages and maps received occasional notice during the next century or so, but it was not until about the beginning of the nineteenth century that the Midewiwin charts and other song records were given much attention. Cass and Schoolcraft called the song records "music boards." They both collected numerous examples, and the latter reproduced many of them (5, 2, 5, and 6). Kohl collected many "bark books," as he called them, in his travels around Lake Superior. Some of these he reproduced in his published account with the explanations he received for them from the Indians (4, pp. 157, 287, 292). He kept looking for musical notes on the birch barks, but in vain (4, p. 286). As Hoffman, who obtained or copied many rolls relating to the Midewiwin, said, the musical rendering of a song by one person might be so different from that of the person from whom he learned it as to be unrecognizable without the words (3).

In more recent years Miss Frances Densmore obtained accompanying drawings for the songs she collected among the Chippewa of northern Minnesota. These drawings, she found, were recognized in distant localities and elicited the same songs. Also, on playing over a song obtained in one community to a member of a distant one, she was shown the proper drawing to accompany it (2).

My efforts to find bark records among the inhabitants of a Chippewa village in northern Michigan this past summer were fruitless. One man was pointed out as the owner of some but he denied having any. In the meetings of the Midewiwin, which are still held several times a year, sand drawings are used to instruct the candidates instead of bark charts. There is a vestige of inscribed wooden tablets to be found in the little paddle-shaped wooden sticks marking each grave in their cemetery. On these sticks the only figure is the totem of the deceased placed upside down to denote death.

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BACTERIOLOGY

Chairman: W. A. JAMIESON, Eli Lilly and Company

The section on bacteriology introduced two new features this year, a panel discussion on a subject of vital interest and a paper reviewing in detail a problem of current importance.

The panel discussion on the teaching of bacteriology was directed by S. E. Hartsell, Purdue University. The following aspects of the subject were presented:

Teaching Bacteriology to Medical Men.—T. B. Rice, Marcus W. Lyon, Jr.

Teaching Bacteriology in an Arts College.—M. S. Markle, A. R. Bechtel.

Teacher Training in Bacteriology.—C. M. Palmer, P. A. Tetrault.

Training Bacteriologists for Health Departments.—C. G. Culbertson, C. K. Calvert.

Training Bacteriologists for Research and Industry.—W. A. Jamieson, Paul Prickett.

Among those participating in the general discussion of this subject were: N. Paul Hudson, Ohio State University; W. LeRoy Mallmann, Michigan State College; Fred W. Tanner, University of Illinois.

Dr. Brueckner's paper on Equine Encephalomyelitis makes available in one article the essential pertinent information and a good bibliography on this timely subject.

Dr. Donna G. Graam was elected chairman of the section for 1940.

ABSTRACT

Possibilities in biological research. W. A. JAMIESON, Eli Lilly and Company.—One often is confronted with the thought that so much has been accomplished in the development of biological therapy that little remains to be done. A review of the advancements in diphtheria immunization, the treatment of pneumonia, the development of germicides, and the improvement in bacterial antigens shows definitely that some of the greatest steps forward have been made after many had considered the problems finished. In addition to the improvement of methods already available, there are the fields of tuberculosis, cancer, *Streptococcus viridans* infections, and rheumatism. Because of our increased knowledge and improved technique, there are even greater possibilities in biological research today than there were a quarter century ago.

Correlation of the Oil-Water Distribution Ratios of Some Substituted Acids with Their Bacteriostatic Properties¹

GEORGE C. GROSS with ED. F. DEGERING and P. A. TETRAULT, Purdue University

As Degering and Goshorn (1) have shown that the bacterial effect of phenylalkanoic acids increases with increasing oil solubility, this work was undertaken to see if such a correlation holds for other acids and for solutions other than aqueous.

Experimental

Twenty-five milliliters of the 0.005 M acid solution was placed in an oil sample bottle and 25 ml. of U.S.P. cottonseed oil added. This mixture was shaken at room temperature for 18 hours. The oil and water emulsion was separated by centrifuging at approximately 2000 r.p.m. Ten milliliters of the aqueous layer was titrated with 0.0096

TABLE I.—The Distribution Ratios of Phenylalkanoic Acids in 5% Ethylene Glycol,* in 10% Ethanol,* and in Water, and Their Bactericidal Properties in Water

Acid	Ratio			Bactericidal Test† (1)	
	5% Glycol	10% Ethanol	Water (1)	Colon.	Aureus
Alpha Series—					
Benzoic.....	5.1	5.0	.....	1/900	1/100
Phenylacetic.....	2.0	1.8	1.8	1/800	1/700
Phenylpropionic.....	6.2	5.8	5.6	1/950	1/650
Phenylbutyric.....	20.9	12.6	14.4	1/1600	1/1600
Phenylvaleric.....	74.0	32.1	26.4	1/2000	1/2300
Omega Series—					
Phenylpropionic.....	9.1	6.8	6.6	1/1000	1/1200
Phenylbutyric.....	25.2	19.3	14.8	1/1300	1/1400
Phenylvaleric.....	42.7	52.0	28.8	1/2500	1/2500

*Highest bacteriostatically inactive concentrations (4).

†Maximum effective dilution is expressed in gm./ml.

¹This is the sixth of a series of articles on the effect of pH and substituent groups on the bacteriostatic and bactericidal properties of certain antiseptics. The other articles are: 1. Antiseptic and bactericidal action of benzoic acid and inorganic salts. *Ind. and Eng. Chem.* 30:646; 2. Preparation of alpha-phenylalkanoic acids and a study of their bactericidal and physical properties. *Journ. Amer. Phar. Assoc.* 27:865-870; 3. Bactericidal properties of commercial antiseptics. *Ind. and Eng. Chem.* 31:742; 4. The effect of para-substituents on the bacteriostatic properties of phenylacetic acid. *Journ. Amer. Phar. Assoc.* 28:514-519; 5. A further study of the effect of pH on the bactericidal properties of some commercial antiseptics. *Ind. and Eng. Chem.* Vol. 48 (1940).

sodium hydroxide, using phenolphthalein as the indicator. Nitrogen was bubbled into the solution to prevent carbon dioxide absorption. Two samples of each acid were shaken, and two titrations were made on each sample. The results checked to 0.10 ml. of base. From the known normality of the original solution and the calculated normality of the extracted solution the ratio can easily be calculated. A blank was run and the normality of the acid solution produced by the solvent in contact with the oil subtracted from the titrated normality.

TABLE II.—Substituted Mandelic Acids—Aqueous Solutions*

Acid	Ratio	Bact. Tests† (2)
Mandelic.....	0.51	1
p-methylmandelic.....	0.28	1-2
p-ethylmandelic.....	0.67	1-4
p-n-propylmandelic.....	2.12	1 or less
p-iso-propylmandelic.....	1.78	1
p-n-butylmandelic.....	5.66	1 or less
p-sec-butylmandelic.....	3.85	1-2
p-ter-butylmandelic.....	3.19	less than 1
p-ter-amylmandelic.....	7.76	1 or less
2,4,6-trimethylmandelic.....	0.78	1.4
p-chloromandelic.....	0.56	2.4

*Prepared by J. L. Riebsomer of DePauw University.

†Based on mandelic acid as 1.

TABLE III.—Para-Substituted Phenylacetic Acids—Aqueous Solutions*

Acids	Ratio	Bacteriostatic Tests†	
		Staph. Aureus	Esch. Coli.
Hydroxyphenylacetic.....	0.09	Less than 1/1000	
Aminophenylacetic.....	0.13	1/1500	1/2000
N-Chloroacetylaminophenylacetic..	0.25	1/3000	1/3000
N-Acetylaminophenylacetic.....	0.28	Less than 1/1000	
Phenylacetic.....	1.85	1/1000	1/1500
Nitrophenylacetic.....	2.71	1/2000	1/610
Methoxyphenylacetic.....	2.79	1/1000	1/1500
Ethoxyphenylacetic.....	8.28	1/1000	Less than 1/1000
Ethylphenylacetic.....	36.1	1/2500	1/1000
Chlorophenylacetic.....	23.7	1/3000	1/1000
Iodophenylacetic.....	42.9	1/4000	Less than 1/1000
Bromophenylacetic.....	73.1	1/5000	Less than 1/1000

*Acids prepared by W. A. Bittenbender.

†Tests indicate the highest dilution negative growth and were made by Professor P. A. Tetrault.

Conclusions

From Table I it is readily seen that, with one exception which is well within the accuracy of the tests, the relative oil-solvent distribution ratio parallels the bactericidal action. Benzoic acid seems to be out of place but follows the general rule that the first member of an homologous series shows unusual properties.

In Table II there is practically no correlation between the distribution ratios and the bacteriological tests except in the first three members. Even here mandelic acid shows a higher distribution ratio but lower bacterial action. This table and Table III bring out the point that the ratios of alkyl-, alkoxy-, and similar substituted compounds cannot be compared with compounds substituted with halogens, or with nitro-, hydroxy-, and other polar groups.

Table III presents fairly consistent data. The ratios show that the *p*-hydroxy-derivative will be the weakest, and this is borne out by the tests. It also shows *p*-nitrophenylacetic acid to be better than phenylacetic acid. Most striking of all the predictions is the curious behavior of the halogen-substituted compounds. The bromo-phenylacetic acid is shown to be better than either the chloro- or the iodophenylacetic acid. The results with *Esch. coli* are quite varied.

In general it can be seen that the oil-water distribution ratio is helpful in predicting the relative bacteriostatic action of certain types of closely related compounds, thus serving as a confirmatory check on standard bacteriostatic or bactericidal tests, but the principle does not appear to be applicable to all types of bacteriostatic agents. The correlation seems to apply, in general, to members of the same homologous series or to members of the same solubility group.

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Sulfo-Merthiolate as a Germicide

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Introduction

Twelve years ago we tested solutions of 'Sulfo-Merthiolate' (Sodium p-Ethyl Mercuri Thiophenylsulfonate, Lilly) for antibacterial action and toxicity. When tested by the Reddish method, it was found to be germicidal in dilutions of 1-1,000 and 1-2,000 but not 1-4,000 for *B. typhosus* and *Staphylococcus aureus*. It was tolerated in doses up to and including 20 mg. per kilogram intravenously by rabbits and in doses up to and including 40 mg. per kilogram intravenously by mice. Preparation of the drug at that time included difficulties of such order that a more complete laboratory study was not then attempted. In general, the drug is quite similar chemically to 'Merthiolate' (Sodium Ethyl Mercuri Thiosalicylate, Lilly) (1 to 11) and possesses the distinct advantage of being soluble over a wide acid, neutral, and alkaline pH range.

During the past two years more adequate amounts of 'Sulfo-Mer-

TABLE I.—Germicidal Test of 'Sulfo-Merthiolate'
Test culture: *B. typhosus*, Hopkins strain, in 0.5 cc. doses. "Medication" at 20°C

Germicide Dilutions (5 cc.)	Readings of culture growth in incubated broth tubes planted with test culture medicated for:					
	5 minutes		10 minutes		15 minutes	
	Direct culture	Sub- culture	Direct culture	Sub- culture	Direct culture	Sub- culture
Phenol 1-80.....	—		—		—	
1-90.....	+		+		—	
'Sulfo-Merthiolate' 1-1000.....	—	—	—	—	—	—
1-2000.....	—	—	—	—	—	—
1-3000.....	—	—	—	—	—	—
1-4000.....	—	+	—	+	—	—

thiolate' have been prepared and a wider laboratory study of the drug made. This report presents the results of these tests.

Experiments

Germicidal tests. 'Sulfo-Merthiolate' was subjected to standard germicidal tests against the Hopkins strain of *B. typhosus* and *Staphylococcus aureus* strain No. 209 at 20°C. Plantings were made in the usual way to tubes of the specified beef extract broth. After two days incubation at 37°C., all negative mercurial tubes were subcultured and reincubated, and both direct and subculture tubes were given final readings seven days after the test was done. The results of these tests are shown in Tables I and II.

These test-tube experiments show that 'Sulfo-Merthiolate' has a strong antibacterial action against the strains of bacteria commonly used in preliminary experiments on various germicides. Inasmuch as "phenol coefficients" of germicides tested in media nearly entirely aqueous in character can have very little importance, we shall not attempt to assay such figures.

The above tests in which 'Sulfo-Merthiolate' dilutions were made in water were repeated with 'Sulfo-Merthiolate' (but not phenol) dilutions made in sterile normal horse serum. One per cent 'Sulfo-Merthiolate'

TABLE II.—Germicidal Test of 'Sulfo-Merthiolate'
Test culture: *Staph. aureus* No. 209 in 0.5 cc. doses. "Medication" at 20°C

Germicide Dilutions (5 cc.)	Readings of culture growth in incubated broth tubes planted with test culture medicated for:					
	5 minutes		10 minutes		15 minutes	
	Direct culture	Sub- culture	Direct culture	Sub- culture	Direct culture	Sub- culture
Phenol 1-60.....	+					
1-70.....	+		+		+	
'Sulfo-Merthiolate' 1-1000.....	-	-	-	-	-	-
1-2000.....	-	-	-	-	-	-
1-3000.....	-	+	-	+	-	+
1-4000.....	-	+	-	+	-	+

TABLE III.—Germicidal 'Test of 'Sulfo-Merthiolate' in Normal Horse Serum
Test culture: *B. typhosus*, Hopkins strain, 0.5 cc. doses. "Medication" at 20°C

Germicide Dilutions (5 cc.)	Readings of culture growth in incubated broth tubes planted with test culture medicated for:					
	5 minutes		10 minutes		15 minutes	
	Direct culture	Sub- culture	Direct culture	Sub- culture	Direct culture	Sub- culture
Phenol 1-80	—		—		—	
1-90.....	+		—		—	
'Sulfo-Merthiolate' 1-1000.....	—	—	—	—	—	—
1-2000.....	—	—	—	—	—	—
1-3000.....	—	—	—	—	—	—
1-4000.....	—	+	—	+	—	+

solution was diluted with whole normal horse serum to prepare the necessary series of germicide dilutions. By this technique the 1-1,000 'Sulfo-Merthiolate' dilution contained 90 per cent horse serum, the 1-2,000 dilution contained 95 per cent horse serum, et cetera; all mercurial dilutions therefore contained 90 per cent or more of whole normal horse serum. The results of these germicidal tests are shown in Tables III and IV. The results indicate that the antibacterial action of 'Sulfo-Merthiolate' persists well in strong serum concentrations. It was further observed that 'Sulfo-Merthiolate' was quite free of serum-precipitating properties.

Bacterial inhibition tests. 'Sulfo-Merthiolate' was diluted in sterile beef extract broth, and 5 cc. amounts of various dilutions were planted with a loop of twenty-four hour broth culture respectively of *B. typhosus*, Hopkins strain, and *S. aureus* No. 209. Both series of tubes were incubated at 37°C. for a week, and readings of growth noted as shown in Tables V and VI. The results indicate that 'Sulfo-Merthiolate' in dilutions of over one in one million to one in four million is inhibitory for ordinary bacteria. These values are somewhat higher than those originally reported of 'Merthiolate' (1) and equal those subsequently reported (10); however, at the time the present tests were conducted, 'Merthiolate' was found to be closely similar to 'Sulfo-Merthiolate' in

inhibition qualities as indicated by the results in footnotes at the bottom of Tables V and VI.

Fungicidal tests. 'Sulfo-Merthiolate' in aqueous solution has been tested against fungi associated with ringworm, using the technique heretofore reported (9). We have noted strong fungicidal action as indicated in Table VII. The 1-10,000 dilution of 'Sulfo-Merthiolate' (but not the 1-20,000 dilution) proved fungicidal for *Trichophyton purpureum* No. 4183, with final reading of all culture tubes being made after seven days incubation. Furthermore, poured plates of this organism showed "clearings" 7.5 cm. in width when streaked with a loop of 'Sulfo-Merthiolate' 1-1,000 and incubated seven days. These test results are quite similar to those reported for 'Merthiolate' (9) and compare favorably with results heretofore obtained with other drugs of this class.

Hemolytic, precipitation, and irritation tests. 'Sulfo-Merthiolate' in concentrations up to and including 1-200 (the strongest tested) in whole horse serum has caused no precipitation when heated at 37°C. for twenty-four hours. It is hemolytic for washed sheep cells (unit equivalent to erythrocytes contained in one-fortieth cc. of whole blood) in a concentration of 1-250 but not 1-500. These values are closely comparable to results obtained with 'Merthiolate' (1 to 11) and indicate considerable tolerance by body fluids and cells.

TABLE IV.—Germicidal Test of 'Sulfo-Merthiolate' in Normal Horse Serum
Test culture: *Staph. aureus* No. 209 in 0.5 cc. doses. "Medication" at 20°C

Germicide Dilutions (5 cc.)	Readings of culture growth in incubated broth tubes planted with test culture medicated for:					
	5 minutes		10 minutes		15 minutes	
	Direct culture	Sub- culture	Direct culture	Sub- culture	Direct culture	Sub- culture
Phenol 1-60.....	—		—		—	
1-70.....	+		+		+	
'Sulfo-Merthiolate' 1-1000.....	—	—	—	—	—	—
1-2000.....	—	—	—	—	—	—
1-3000.....	—	+	—	—	—	—
1-4000.....	—	+	—	+	—	—

TABLE V.—Bacterial Inhibition Tests of 'Sulfo-Merthiolate'
Test culture: *B. Typhosus*, Hopkins strain.

Germicide Dilutions in Broth (5 cc.)	Readings of culture growth in broth tubes containing varying dilutions of germicide and planted with 1 loop 24-hour broth culture and incubated for:				
	24 hours	96 hours	120 hours	144 hours	168 hours
'Sulfo-Merthiolate'					
1-600,000	—	—	—	—	—
1-800,000	—	—	—	—	—
1-1,000,000	—	—	—	—	—
1-1,200,000	—	—	—	—	—
1-1,400,000	—	—	—	+	+
1-1,600,000	—	+	+	+	+

Note: On same day of this test 'Merthiolate' 1-1,200,000 proved inhibitory on same culture at 168 hours incubation.

We have subjected 'Sulfo-Merthiolate' to human skin tests on individuals quite susceptible to several irritating substances, including common adhesive plaster. In these tests different concentrations of 'Sulfo-Merthiolate' were applied to thoroughly cleansed skin of the upper arm by means of wet cotton pledgets held in place under rubber dam for eighteen hours. Dilutions of bactericidal activity (1-1000 to 1-4,000) showed no reaction whatever, either when aged up to a year or when heated at 60°C. for a month. To get a final end point of beginning irritation comprising slight redness, it was necessary to use a concentration of 1-25. Under the same condition 'Merthiolate' has given a slight reaction at a concentration of 1-100.

When tested under the same conditions, we have found 'Sulfo-Merthiolate' non-irritating to human skin when incorporated as a 1-1,000 concentration either in a dusting powder base, tragacanth jelly base, or tincture, or as a 1-2,000 concentration in an ointment base.

Toxicity tests. Six mice injected intravenously with an early preparation of 'Sulfo-Merthiolate' indicated the drug was tolerated in doses up to and including 40 mg. per kilogram. Twenty rabbits injected intravenously with four different preparations indicated that doses of 20 mg. per kilogram, but not 30 mg., were tolerated. We have recently treated forty-eight rats intravenously with 'Sulfo-Merthiolate' in doses of 20 mg. per kilogram up to 75 mg. per kilogram with increments of 5 mg.

doses, each of the twelve doses therefore being administered to four rats. At the end of seven days one rat out of four had died on the 30, 45, 55, 60, 65, and 70 mg. doses, and two rats out of four had died on the 75 mg. dose. We then treated sixteen rats intravenously with doses of 40, 60, 80, and 100 mg. per kilogram, using four rats on each dose. Within seven days none of the rats on 40 or 60 mg. doses had died. Two rats, quite ill on the 80 mg. doses, were sacrificed on the fifth day for study; the other two died by the seventh day. All four rats on the 100 mg. dose died by the seventh day, and one of these was found sufficiently early for microscopic study. Both of the rats treated intravenously with 80 mg. 'Sulfo-Merthiolate' per kilogram and sacrificed on the fifth day presented empty urinary bladders on autopsy and possibly were anuric. Only the kidneys showed noteworthy lesions. The first animal had many convoluted tubules with parenchymatous degeneration and a few with necrosis. Many tubules also showed evidence of regeneration and were lined by cells which had flattened, had basophilic cytoplasm, and showed numerous mitoses. The second animal's kidneys resembled those of the first. Many convoluted tubules were lined by regenerated cells and mitoses were frequently seen.

TABLE VI.—Bacterial Inhibition Tests of 'Sulfo-Merthiolate'

Test culture: *Staphylococcus aureus* No. 209.

Germicide Dilutions in Broth (5 cc.)	Readings of culture growth in broth tubes containing varying dilutions of germicide and planted with 1 loop 24-hour broth culture and incubated for:				
	24 hours	96 hours	120 hours	144 hours	168 hours
'Sulfo-Merthiolate' 1-1,000,000.....	—	—	—	—	—
1-2,000,000.....	—	—	—	—	—
1-3,000,000.....	—	—	—	—	—
1-4,000,000.....	—	—	—	—	—
1-5,000,000.....	—	+	+	+	+
1-6,000,000.....	—	+	+	+	+
1-7,000,000.....	+	+	+	+	+

Note: On same day of this test 'Merthiolate' 1-5,000,000 proved inhibitory for same culture at 168 hours incubation.

TABLE VII.—Fungicidal Test of 'Sulfo-Merthiolate'

Test culture: *Trichophyton purpureum* No. 4183 of the American Type Culture Collection in doses of 0.5 cc. of a 10 cc. water suspension of 7-day slant culture. "Medication" at 20°C

Germicide dilutions (5 cc.)	Readings of culture growth, after 7 days incubation, in agar tubes planted with test culture medicated for:		
	5 minutes	10 minutes	15 minutes
'Sulfo-Merthiolate' 1-1000.....	—	—	—
1-5000.....	—	—	—
1-10,000.....	—	—	—
1-20,000.....	+	—	—
1-40,000.....	+	+	+
1-60,000.....	+	+	+

The rat treated intravenously with 100 mg. 'Sulfo-Merthiolate' per kilogram and found dead on the sixth day was possibly anuric, the bladder being empty. Microscopically the kidneys were seen to be severely injured. The epithelium of many of the glomerular capsules and convoluted tubules showed severe parenchymatous degeneration. Some convoluted tubules showed fatty degeneration, and in many the cells were necrotic. In a few foci, there was evidence of slight regeneration.

Aside from the animals enumerated above, thirty guinea pigs have been injected hypodermically with 1 cc. of diphtheria toxoid preserved with 'Sulfo-Merthiolate' 1-10,000. No local lesions were observed. These guinea pigs will be referred to further.

'Sulfo-Merthiolate' as a biological preservative. Close similarity of 'Sulfo-Merthiolate' to 'Merthiolate' as noted thus far indicated the former might be used as a biological preservative as has 'Merthiolate' (11). A comparative test was, therefore, conducted, using a single lot of diphtheria toxoid subsequently divided into two portions. To one of these, 'Sulfo-Merthiolate' 1-10,000 was added, and, to the other, 'Merthiolate' 1-10,000 was added. Both antigens were then heated at 37°C. for four months. Immunization of guinea pigs was done with samples of toxoid removed after two months heating and after four months heating. In these tests a total of sixty guinea pigs of 300 grams weight were given single 1 cc. doses of the respective toxoids. For testing the degree of anti-diphtheria immunity which these toxoids incited, 10, 20, and 40

MLD of diphtheria toxin were administered to different subgroups of forty-five of these guinea pigs one month after they had received the single immunizing dose of toxoid. Fifteen guinea pigs had died of intercurrent pneumonias. Table VIII shows the results of these immunity tests. Totals of all survivals and deaths following the toxin doses used show that 48 per cent of the guinea pigs immunized with 'Sulfo-Merthiolate'-preserved toxoid survived and 40 per cent of the guinea pigs immunized with 'Merthiolate'-preserved toxoid survived. The actual number of animals used in each of the final groups was, however, too small to make exact comparisons. It appears that further experimental biological preservation with 'Sulfo-Merthiolate' is indicated, inasmuch as its showing in toxoid is a good one.

Discussion

The laboratory tests herein reported show that in biological action 'Sulfo-Merthiolate' (Sodium p-Ethyl Mercuri Thiophenylsulfonate, Lilly) is quite similar to 'Merthiolate' (Sodium Ethyl Mercuri Thiosalicylate, Lilly). Both compounds possess antibacterial action of about the same potency. Both have relatively low toxicity, in comparison with others of this class of drugs, when injected directly into the blood stream. There is almost complete freedom from protein precipitating qualities, and this germicide has a large margin of safety between undesirable toxic properties on the one hand and desirable antibacterial properties on the other hand.

The tests reported here, comprising evidence of both germicidal and strong bacteriostatic action as well as marked freedom from toxicity, are such as to indicate that 'Sulfo-Merthiolate' could exert a very pro-

TABLE VIII.—Comparative Immunizing Properties of Diphtheria Toxoid Preserved with 'Sulfo-Merthiolate' and Heated Two and Four Months at 37°C.

Diphtheria Toxoid Number	Number of Months Heated	Results of immunity tests conducted by injecting toxoid-treated guinea pigs with different amounts of diphtheria toxin					
		10 MLD		20 MLD		40 MLD	
		died	lived	died	lived	died	lived
B-4318A with 'Merthiolate' 1-10,000	2	2	2	0	4	1	3
	4	1	1	2	1	2	1
B-4318B with 'Sulfo-Merthiolate' 1-10,000	2	1	3	2	2	4	0
	4	1	3	2	3	2	2

longed antibacterial action when used clinically. On the basis of nearly all newer knowledge of immunology and chemotherapy, a moderately strong and persistent antibacterial action would be more likely to be effective than strong initial germicidal action without any mechanism (bacteriostasis) to make this persistent. 'Sulfo-Merthiolate', soluble in both acid and alkaline pH ranges and having both germicidal and bacteriostatic action, could, therefore, be recommended for further clinical trial.

Conclusions

1. A series of biological tests indicates 'Sulfo-Merthiolate' is a close counterpart of 'Merthiolate' in antiseptic action.
2. Concentrations of 1-2,000 to 1-3,000 of 'Sulfo-Merthiolate' are effective against staphylococci and typhoid bacilli when tested in blood serum.
3. Concentrations of 1-1,000,000 to 1-4,000,000 of 'Sulfo-Merthiolate' inhibit the growth of staphylococci and typhoid bacilli.
4. 'Sulfo-Merthiolate' in concentrations up to and including 1-200 does not precipitate serum. A 1-10,000 concentration is indicated as a biological preservative.
5. 'Sulfo-Merthiolate' in a concentration of 1-25 (i.e., forty times as strong as a stock 1-1,000 dilution) showed a beginning threshold of skin irritation.
6. White rats tolerate 40 to 50 mgm. 'Sulfo-Merthiolate' per kilo intravenously.
7. 'Sulfo-Merthiolate' is soluble over a wide acid and alkaline pH range.

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- ('Merthiolate,' included in the titles of papers in the foregoing references, is the trade-mark of Eli Lilly and Company for its sodium ethyl mercuri thiosalicylate.)

Equine Encephalomyelitis

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Equine encephalomyelitis has been recognized as a virus disease of horses since 1931. In that year, Meyer, Haring, and Howitt (1), investigating an outbreak of cerebro-spinal disease among California horses, established the affliction as an infectious disease of virus origin. Previous to this time, many outbreaks, characterized by the same symptoms but of unknown etiology, had been reported. These early cases were referred to by a number of different names, some of the most common terms being Borna disease, forage poisoning, botulism, staggers, and cerebro-spinal meningitis. In 1912, 35,000 horses died as a result of an epizootic of a disease called "staggers," and, in 1919, Colorado alone lost almost 1,800 head to forage poisoning (2). It is now generally suspected that both of these epizootics were caused by the virus of encephalomyelitis. Forage poisoning, a disease caused by the consumption of moldy corn, does affect horses, but, unfortunately, the name has not been restricted to cases where toxic food is definitely involved. It is also true that botulism may affect horses, but these cases are rare and need not be confused with encephalomyelitis. Other bacterial and toxic infections of the brain and spinal cord would naturally lead to paralytic symptoms, somewhat resembling those of encephalomyelitis, but should not confuse one familiar with the latter disease. Virus diseases closely related to the American encephalomyelitis have been reported in Germany, France, and Russia, but all of these diseases are immunologically distinct.

In 1933 a disease very similar to that noted in California was reported as affecting horses in Virginia, Maryland, and Delaware (3). Except for a slight difference in incubation period and virulence, the outbreak was indistinguishable from that in the west. Records and Vawter (4, 5) found that in guinea pigs no cross immunity between the two could be demonstrated. Guinea pigs, injected with intranasally collected virus from horses suffering from the eastern disease, upon contracting the disease and surviving, were immune to a second injection of the same virus but succumbed to the western virus. In further experiments by these authors (4, 5), six out of eight horses immune to the western type also resisted the eastern type. These authors, therefore, decided that the chief difference in the virus of the two epizootics was one of virulence. However, Shahan and Giltner (3) and TenBroeck and Merrill (6), in 1933, published evidence that the eastern and western viruses were immunologically distinct. It has since been shown repeatedly that animals immune to the western virus are susceptible to infection by the eastern virus and that the reverse is also true. The disease is now known as eastern or western type encephalomyelitis in recognition of the two immunological types.

Typing tests which have been made by the Bureau of Animal Industries (7) and by investigators in private laboratories have shown

that the Appalachian Mountains form the dividing line between the eastern and western types of the disease. Until the summer of 1939, no case of infection with eastern type virus had been found west of this range, and no western type had been found east of the line. However, this summer Scofield reported a case of eastern type encephalomyelitis in Ontario, and the Bureau of Animal Industries reported another eastern type infection on an Alabama farm.

The causative virus of encephalomyelitis localizes its damage to the higher nervous centers of the brain and spinal cord. The symptoms of the disease are obviously the results of pathological changes in the brain and cord. The infection leaves practically no gross lesions, and only examination of nervous tissue yields evidence of specific pathological change. Hurst (8) made a study of the histopathology in horses and laboratory animals. The most striking microscopic lesions reported by him are: acute primary degeneration of nerve cells, nuclear inclusions in neurons, polymorphonuclear infiltration, especially in grey matter, and perivascular cuffing with mono- and polymorphonuclear cells. Eastern and western viruses cause the same changes, but the extent of damage is less in the case of western infection. In certain stages, the histopathology of the two types may be indistinguishable. A very intensive study of the histopathology of the nervous system in encephalomyelitis-infected guinea pigs has also been made by King (9). Histological changes and the histogenesis of the disease processes are described in detail.

The course of infection in encephalomyelitis is usually divided into three stages. During the first stage there is a rise in temperature, but other effects are so slight that this phase usually escapes detection in all but experimental cases. The second stage brings on the objective symptoms that result in the recognition of field cases. Infected animals show clearly the signs of nervous involvement with paralysis and incoordination apparent. The specific manner in which the disease manifests itself varies somewhat with individual horses, but typical symptoms are as follows: Normal skin irritability may give way to hypersensitiveness, or, at the other extreme, to complete lack of sensation. Partial or complete inappetence is often noted and grinding of the teeth, yawning, and twitching of various body muscles are common. In many cases there is a tendency to walk in circles. Later the animal becomes drowsy; this is so typical that the disease is widely known among the laity as "sleeping sickness." As paralysis and incoordination develop, the animal stands with feet spread wide or leans for support against stall partitions or fences. Occasionally, at the end of this second stage the animal manifests great excitement and irritability.

If the disease runs a fatal course, the third stage is that of complete incoordination in which animals are unable to stand but lie in a state of complete paralysis or thrash violently with running movements of the legs. This stage usually terminates quickly in death, but occasionally horses remain comatose for several days.

In small laboratory animals the usual symptoms are those of advancing paralysis, leading to coma and death. Mice and less often guinea pigs may suffer a convulsive spell just before the stage of pros-

tration. Since the intracerebral method of infection is the usual one in experimental cases, symptoms progress more rapidly and regularly than in field cases.

Diagnosis of field cases is made on the basis of the above clinical picture and the seasonal and epizootic character of the disease. Laboratory diagnosis, while an indispensable aid to research, is too slow for application to individual field cases. However, in investigating the possibility of spread into new areas or suspected out-of-season cases or in establishing the identity of the disease early in an epizootic, laboratory diagnosis is extremely useful. The slowest but surest means of diagnosing the disease is the inoculation of laboratory animals with brain tissue specimens from the suspected case, using normal animals and animals immune to both types of the virus. When such a group of animals is inoculated intracerebrally with a suspension of properly handled encephalomyelitis tissue, the normal animals and one group of immune animals will succumb. Such an immunological test leaves little question as to the identity of the disease and its type. A characteristic histopathology furnishes another means of laboratory diagnosis, but specimens for this test must be carefully handled and preserved, and the comparatively complicated and expensive procedure of tissue sectioning is necessary for reliable results. In recovered or suspected subclinical cases, neutralization tests with patients' serum and known virus often result in a reliable diagnosis.

The method by which the virus enters its natural host in the field is not definitely established. Kelser (10) has presented evidence that mosquitoes may carry the virus, and Merrill and TenBroeck (11) in 1935 published proof that *Aedes aegypti* can harbor the virus for a period of at least two months, provided it is fed a high concentration of the virus. Madsen and Knowlton (12) reported that several other species of the genus *Aedes* may carry the disease. However, there is no transmission of the virus between the male and female mosquitoes; nor are eggs and larvae from infected females or those grown in infected media dangerous as adults. The possibility of transmission by mosquitoes has been made more plausible by the demonstration of the virus in the blood stream of infected animals. The invasion of the blood stream by the virus is confined to a short period during the first temperature rise and just before the onset of objective symptoms. However, workers engaged in research for the United States Bureau of Animal Industries (7) have failed to detect virus in mosquitoes collected from epizootic areas. The obstacles in the way of anyone undertaking such experiments are great, and only positive results would be of great significance. There are still a great many who cling to the idea that an insect vector will some day be incriminated in the spread of encephalomyelitis. Those who believe in other methods of transmission have even less evidence in their support. It is unlikely that direct contact plays an important role for it is quite common for a few animals to contract the disease on the same premises where others in close contact remain healthy. While Records and Vawter (5) found virus in nasal washings of artificially infected horses, virus has not yet been detected in urine,

nasal washings, or even in nasal mucosa of naturally infected animals (13).

The path followed by the virus, once it gains entrance to the host, has not yet been completely worked out. It is easily demonstrated, however, that the virus invades the blood stream soon after its establishment in peripheral tissues. King (14) studied the pathogenesis of the disease and concluded that direct invasion of the brain from the blood stream seems to be the principal method of pathogenesis. Once in the nervous tissue, the virus may spread by different methods. In some cases affected regions bear a striking anatomical relationship; in other cases foci are joined by entirely unaffected anatomical connections. Thus the virus may travel along nerve connections or settle in several distinct areas simultaneously by deposition from the blood stream.

In addition to the problem of transmission during epizootics, we are faced with the question of how these epizootics start. It is one of the characteristics of equine encephalomyelitis that cases never occur after the first killing frost of the fall or before the warm weather of late spring. It is quite unlikely that horses themselves harbor the virus over this winter period. No success has met attempts to detect equine carriers of the virus. Furthermore, many horses are transferred from the eastern to the western zone, and vice versa, without disturbing the geographical distribution of the two types of virus. However, great progress is being made in the detection of other hosts to the virus. The disease has infected humans, monkeys, guinea pigs, mice and other laboratory animals, pheasants and pigeons, to name only a few possible hosts. Should it be proved that the occurrence of encephalomyelitis virus in migratory fowl is not a rare phenomenon, we shall be justified in closely associating birds with the epidemiology of encephalomyelitis. In this connection, susceptibility of human beings must not be overlooked. Outside of laboratory accidents, the source of infection in human cases is as mysterious as that of equine cases. A number of cases reported in Massachusetts in children were of unknown origin since there had never been any contact with horses or any other common source of the virus.

With so little known about the virus and its habits, it is quite natural that the treatment of encephalomyelitis is almost entirely symptomatic. The most important step in treatment, which acts directly against the virus, is the administration of antiserum of which more will be said later. Prerequisite to successful treatment is the provision of a quiet, restful atmosphere. Bright lights, noises, and all factors conducive to excitement are to be avoided. To combat dehydration, water must be administered. If no other way is possible, intravenous injections of water sometimes give good results. Harsh purgatives, because of the loss of water they cause, are contra-indicated, but mild laxatives are sometimes necessary and beneficial. Of course, the animal must be assisted in taking nourishment where paralysis has made chewing and swallowing difficult or impossible. These are the general lines of treatment. Many veterinarians have reported good results with various methods, but all such methods are based on the fundamentals of treating symptoms for immediate relief and injecting

serums to combat the virus. Some veterinarians are skeptical as to the therapeutic value of antiserum. It is true that, unless serum production is very carefully controlled, a product of low protective titre may result, but it is quite possible to produce a serum of high antibody content in animals in which, following vaccination, a state of hyper-immunity has been induced by the repeated injection of living virus. Previous to last year, the hyper-immunizing virus consisted of an emulsion of infected brain tissue. Antiserum produced by this method was of great value in treatment and prophylaxis but was still below the efficiency of antisera of other diseases. With the development of the chick embryo propagated virus, an immunizing agent of far greater potency than was formerly possible has been made available. Chick embryo antigen contains as much as 100,000 times the virus concentration of brain tissue antigens. As a consequence of the greater stimulation of antibody mechanisms in serum-producing horses, anti-encephalomyelitis serum is now, at least in experimental trials, a far better prophylactic and therapeutic agent than it was a short time ago. The sudden dropping off of the incidence of encephalomyelitis this year has made impossible any field comparisons of the old and new serums, and it is consequently impossible to state how the new type serum will act in an actual epizootic. But it can be stated that in place of delicate neutralization tests protection tests are practical for titrating the new serum.

It is in the field of prevention that the greatest advances in the battle against encephalomyelitis have been made. To many the story of the development of a reliable vaccine in an almost incredibly short time is the most interesting phase of any consideration of the disease. Aside from the purely practical angle of saving horses' lives, the history of the vaccine is important because of the methods involved and because of new light shed on virus immunological problems during the investigations.

In 1934 Records and Vawter (15) published work on equine encephalomyelitis immunization through the use of active virus. They found subcutaneous injections of the virus would stimulate immunity but were extremely dangerous in that a great many animals succumbed to the disease during the process of immunization. Their attempts to inactivate the virus without disturbing the antigenic complex were unsuccessful. In the same year Howitt (16) also reported experiments designed to develop a safe yet efficient vaccine. She found that one small dose of live virus would immunize guinea pigs, but the same high incidence of infection followed vaccination that resulted in Records' experiments also occurred in the work of Howitt. Howitt also tried serum virus mixtures for vaccination. Practically no protection resulted from the injection of mixtures of serum and virus unless an excess of virus was present. It was also necessary to follow the initial serum-virus treatment with several injections of active virus. Although this method was safer than the former attempts of the author, the possibility of infection was still far too great to justify field use. In this connection it might be mentioned that Olitsky (17) in 1938 and Gochenour (18) in 1939 have published conclusive evidence that antiserum has a block-

ing effect on the action of vaccine. Gochenour advises against vaccination for a period of at least two weeks after administration of antiserum and presents experiments with guinea pigs to show that within this period prophylactic doses of serum prevent the action of vaccine.

In 1936 Olitsky and Cox (19) published a paper dealing with the quantitative aspects of vaccination with active virus. They found that active untreated virus, virus absorbed on aluminum gel, and virus precipitated by tannin were all equally efficient as immunizing agents and, furthermore, that 3000 to 30,000 m.i.d.'s of any of these agents were necessary to protect against intracerebral infection. Later in the same year, Olitsky (20), acting on the encouraging results reported by Shahon and Giltner (21), made a further investigation of the possibilities of formalized virus as a vaccine. He found that the method of preparing such vaccines was of great significance, and this may explain the failure of earlier attempts. Fresh tissues of high virus content, not over-formalized, gave consistently good results. Vaccine thus prepared has good protective and keeping qualities as long as the formalin is not neutralized.

Since the formalized virus was completely inactivated and the possibility of accidental infection nullified, field experiments were undertaken with success. As a consequence, a formalized brain tissue vaccine was produced by commercial houses and was used with gratifying but not complete success during the epizootics of 1937 and 1938.

In 1935 Higbee and Howitt (22) had succeeded in growing the virus of encephalomyelitis in the developing chick embryo, and Beard, et al, showed that both types of virus grew on this medium in greater concentrations than had hitherto been possible. It was then found that the chick embryo virus could be completely inactivated in the presence of 0.4 per cent formalin while retaining its antigenic integrity. Therefore, it became possible to make a vaccine which was not only entirely safe but, because of its high virus concentration, was extremely efficient. Guinea pigs inoculated with two doses of the chick embryo vaccine are solidly immune seventeen days or less from the time of the first inoculation. Guinea pigs so protected resist many lethal doses of the virus injected intracerebrally; unvaccinated controls invariably died.

Very briefly, the method of preparation of the chick vaccine is as follows. Fertile eggs incubated ten to twelve days make the best medium for propagation of the virus. A 20 per cent suspension of brain tissue virus may be inoculated by any of the accepted methods for virus propagation in eggs. The embryo is so susceptible to the virus, however, that there seems to be no need for natural or artificial air sac methods. If the virus is placed just beneath the shell of the egg, it will be in close enough contact to the chorioallantoic membrane so that infection and death will result in from 24 to 48 hours. Dead embryos harvested aseptically after the first virus passage and used in a 1 to 5 per cent suspension to inoculate other eggs will consistently cause death within 20 hours for an indefinite number of passages. After three or four egg passages, the virus has become adapted to the egg and fixed and is ready for use in the preparation of vaccine. Both the chick and its membranes are ground as finely as possible and suspended in physiological saline

solution. As is true of all tissue vaccines, the more thoroughly the chick tissue is ground, the more virus may be expected to be released into the diluent. Formalin sufficient to make a final concentration of 0.4 per cent may be added conveniently with the diluent. Forty-eight hours at room temperature is a safe time period to allow for inactivation of the virus, and at the end of this time the vaccine should immediately be refrigerated. Guinea pigs inoculated intracerebrally with the vaccine will serve to show the absence of any active virus. A potency test of satisfactory vaccine against a heterologous strain of the same type of virus should result in 100 per cent protection of principles and 100 per cent death of controls. A 1 to 500 dilution of guinea pig brain virus is the usual exposure dose in potency tests. Such a dose will bring complete prostration or death to controls in five days for the western virus and four days for the eastern virus.

With the new chick vaccine available, an important research tool has been added to the laboratory workers' collection. Studies on epidemiology, etiology, and immunology of the disease should advance more rapidly, now that a safe, sure method of immunization is known. It should be emphasized that the efficiency of the vaccine may prove important, not only in solving problems of equine encephalomyelitis but also in solving the fundamental problems of general virus immunology.

I should like, in conclusion, to mention that the study of the mechanism of immunity to encephalomyelitis is a fascinating research problem which is still to a great degree unsolved. It is quite natural that, in the face of costly and widespread epizootics, most research has been undertaken with a view to halting the spread of the disease. That objective is now well advanced toward accomplishment. The means of control of encephalomyelitis may be found in chick embryo vaccine if extensive vaccination can be practiced over a long period of time. But, in our haste to accomplish the practical end of saving horses' lives, we have to a great extent failed to inquire into the mechanisms of the results we have been able to bring about. For instance, we know that intracerebral exposure is more effective in causing fatal encephalomyelitis than any other method, and King (9) has shown that there is a difference in brain pathology in various types of inoculation. The reason for this difference needs more investigation. Olitsky has pointed out that antiserum is much less effective against intracerebral inoculation than intraperitoneal inoculation and mentions that, when virus enters nerve tissue, antiserum seems of little value. Yet, vaccinated animals resist incredibly strong doses of virus directly into the brain. Does this mean that actively immune animals are protected chiefly by tissue immunity? Does it also mean that serum from hyperimmunized animals protects other animals by destroying virus in the blood stream or at the point of inoculation? Such problems as these need more than philosophical consideration, and it is possible that chick embryo virus, with its ability to stimulate the production of more potent antiserum in hyperimmunized animals and a better active immunity in vaccinated animals, will lead to an experimental solution of many virus immunological problems.

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BOTANY

Chairman: WINONA H. WELCH, DePauw University

The usual interest shown in the program of this section was maintained. About 70 to 75 were in attendance.

Ralph M. Kriebel, of the Soil Conservation Service, was elected chairman of the section for 1940.

ABSTRACTS

Dr. John Thomas Plummer, pioneer Indiana botanist. LAWRENCE J. KING, Richmond.—Little notice has been given to the scientific work of an early physician of Richmond, Indiana, Dr. John Thomas Plummer (1807-1865). From an extensive search into the early scientific literature, it has been possible to construct a bibliography of approximately 145 titles. These papers cover many subjects from botany to philology. Some of his first writings were botanical, and these are among the earliest contributions to the flora of Indiana. An extensive biography is in preparation.

Pteridophytes of the Lower Yangtze Valley. CHARLES E. DE VOL, Indiana University.—This is a list of 154 species and varieties of pteridophytes collected over a period of six years. Keys, descriptions of genera, critical taxonomic notes, and Chinese names are given. The paper includes a brief history of Chinese pteridology and a digest of the literature. Two new species, *Athyrium Devollii* Ching and *Athyrium giganteum* De Vol, are described; *Monachosorum flagellare* (Max.) Hayata and *Hymenophyllum Wrightii* v.d.B. are reported from China for the first time; and twenty-two species new to the Lushan area are listed.

A key to the ferns and fern allies of northeastern North America. RAY C. FRIESNER, Butler University.—The appearance of Broun's *Index to North American Ferns* has done much to stabilize the nomenclature of this taxonomic group. So many new species, varieties, and forms are recognized that it is highly desirable that keys be constructed for their determination since there are none at present available except those scattered through periodical literature. The present key covers all species and varieties occurring within the range of Gray's *Manual*.

The distribution in Indiana of *Quercus ellipsoidalis* E. J. Hill. RALPH M. KRIEBEL, Bedford.—A study of the distribution of *Quercus ellipsoidalis* E. J. Hill has shown that it is definitely limited to that region of sand ridges, plains, and marshes in the northern part of the state where the substratum is sandy or gravelly and is now artificially drained. It is an inhabitant of the Plainfield soil types and is found more frequently on the heavier types of soil. Apparently, it is absent on the sand dunes around Lake Michigan but is a frequent to a common

tree in the sandy areas in the Kankakee Valley. It is mostly associated with *Quercus velutina* Lam. and *Quercus palustris* Muench. Specimens taken from two to eight trees from each of 18 counties are deposited in the author's herbarium, and duplicates of most of them were deposited in other herbaria in Indiana and in several of the larger ones outside of the state.

A post-Pleistocene fossil pollen study of two northern Indiana bogs. FRANK A. HAMP, Butler University.—The study deals with pollen analyses of the Lakeville and Round Lake bogs in deposits of late Wisconsin glaciation in northern Indiana. Both bogs show about the same successional record. Significant climatic changes from cool-moist to warm-dry are indicated by a striking decrease in *Abies* and *Picea* and appearance of numerous deciduous genera. The Lakeville bog showed a brief *Pinus* dominance in the 28-foot level which was absent in the Round Lake bog. *Picea* and *Pinus* persisted to the top foot level in both bogs. From the 27-foot level in the Round Lake bog and 26-foot level in the Lakeville bog, the forest dominance was essentially *Quercus-Carya* with a weaker co-dominance of *Acer* indicated in seven levels.

Correlation of radii in asymmetrical growth of *Quercus velutina*. RAY C. FRIESNER, Butler University.—Microscopic measurements of year ring growth made from 11 to 15 radii, each for four asymmetrical stump sections, 120 years old, of *Quercus velutina* show that there is a general gross correlation of growth increments, but the precise amount varies greatly. When all the radii of a particular section are compared for each year, we find 100% conformity for 8% to 10% of the years, 80% for 31% to 32% of the years, and 73% to 75% for 39% to 42% of the years. Conformity is greater in years of pronounced change. Curves plotted for successive radii of each individual year of growth show that growth follows a rhythmic pattern as the curve moves around any particular year. This is more pronounced in periods when annual growth increase is 2 mm. or more. External environmental factors play no recognizable role in determining asymmetrical growth.

Formation of the perispore of the megaspore of *Isoetes Engelmanni*. DOROTHY PARKER, St. Mary's College, Notre Dame.—The perispore of *Isoetes Engelmanni* is exogenous in origin. The formation involves an unusual multiplication of tapetal cells. The normal function of the tapetum is that of supplying food, but these cells go through a complicated process of division into morphological units which supply the megaspores with a perispore.

History of Indiana Bryology

WINONA H. WELCH, DePauw University

Bryophytes are little studied in comparison with the spermatophytes, and the number of students interested in this group of plants is small. Indiana is fortunate in having had observations made and recorded in the field of bryology over a period of approximately 65 years.

The earliest published record of scientific interest in the bryophytes of Indiana, noted by the author, is that of Prof. A. H. Young¹ of Hanover College, Hanover, Indiana, in *Botanical Gazette* 2:61-62, 1876. Mr. Young states in this article that the mosses were collected during the fall and winter of 1875 and that he was assisted in the identifications by Prof. D. C. Eaton of Yale College and Mr. Eugene A. Rau of Bethlehem, Pennsylvania. The "Bryological Notes" prepared by Prof. Young concern 70 different species, collected in Jefferson county. The Young Herbarium of Bryophytes, consisting of several hundred packets, is in the Indiana University Herbarium.

Mrs. Mary Parry Haines,² a student of geology and paleontology, published two papers concerning the bryophytes of Wayne county, Indiana, in 1878 and 1879. I have had no success in locating the specimens upon which her publications were based.

Names of bryophytes from another portion of the state were published in 1879 by John Merle Coulter³ in "The Flora of Northern Indiana". The Coulter specimens are in The Field Museum of Natural History.

Lucien Marcus Underwood,⁴ in 1882, published a list of North American Hepaticae in which Indiana is represented. Probably L. M. Underwood, Professor of Botany in DePauw University, 1891-1895, is one of the most widely known American bryologists who has done extensive work with this group of plants in Indiana. Prof. Underwood was Director of the Botanical Division of the Indiana State Biological Survey of the Indiana Academy of Science and in 1893 had in his herbarium approximately 10,000 specimens of bryophytes, representing 900 species of mosses and 1,300 species of liverworts. In 1891, Prof. Underwood reported the finding of the rare moss, *Bryoxiphium norvegicum* (Bridel) Mitten in great abundance on the sandstone rocks of

¹Born in Avondale, Cincinnati, Ohio, in 1852; died in Hanover, Indiana, in 1926. James L. White & Co. of New York published his biography in the *National Encyclopedia of America* in 1926.

²Born in Cinnaminson, New Jersey, Dec. 24, 1826; died at Richmond, Indiana, Dec. 8, 1884. Was custodian of the Paleontology Department of the Museum of the Scientific Association of Richmond, Indiana. *Transactions of the Scientific Association of Richmond, Indiana*, June 1, 1876. *History of Wayne county, Indiana*, 1884, page 187.

³Born in Ningpo, China, Nov. 20, 1851; died in Yonkers, New York, Dec. 23, 1928.

⁴Born in New Woodstock, New York, Oct. 26, 1853; died in Redding, Connecticut, Nov. 16, 1907. Curtis, Carlton Clarence, 1908. A biographical sketch of Lucien Marcus Underwood. *Bull. Torrey Bot. Club* 35:1-12. Barnhart, John Hendley, 1908. The published work of Lucien M. Underwood. *Bull. Torrey Bot. Club* 35:17-38.

Fern, Putnam county. The Indiana station was the fourth in the fourth state, Sullivant making the first report in 1846 for Ohio, Rau for Pennsylvania, and Mrs. Elizabeth G. Britton in 1883 for Wisconsin. Underwood also reported in 1891 the first collection in America of the hepatic, *Fossombronina cristata* Lindberg, having found it on clay banks at Fern. Among the 212 titles of the published works of Lucien M. Underwood, 31 concern Hepaticae. In nine of these, liverworts of Indiana are discussed. Prof. Underwood left only a small portion of his bryophyte collection in the DePauw University Herbarium. The Lucien M. Underwood Herbarium was purchased by The New York Botanical Garden.

In 1886, Bulletin I of the Purdue University School of Science contained the "Analytical Key to the Genera of Mosses, recognized in Lesquereux and James's Manual of the Mosses of North America," prepared by Charles Reid Barnes,⁵ Professor of Botany, Purdue University, 1880-1885. Although the edition was large, the demand soon exhausted the supply of bulletins. Encouraged by these requests, in 1890 he published keys to the species of North American mosses recognized by Lesquereux and James. This edition was soon exhausted, and in 1896 Prof. Barnes published "Analytical Keys to the Genera and Species of North American Mosses." The taxonomic work of Prof. Barnes in the field of bryology won for him recognition among botanists. The analytical key was considered to be one of his most important publications on mosses. His specimens have been deposited in The Field Museum of Natural History and in the Herbarium of the University of Wisconsin.

Dr. W. S. Blatchley included a list of 13 species of mosses in his thesis concerning plants of Monroe county, in 1887.

Ellsworth Jerome Hill,⁶ a teacher, minister, and botanist, collected extensively, leaving approximately 16,000 sheets in his herbarium, at the time of his death. Mr. Hill devoted his last 10 or 12 years to the study of mosses of the Chicago region. He prepared descriptions of 133 species. In the list of 162 titles of the E. J. Hill publications, there are 10 which concern bryophytes. Five of these articles discuss Indiana mosses and liverworts. The University of Illinois purchased the E. J. Hill Herbarium. Some of his mosses are also in the Herbarium of The Field Museum of Natural History.

Dr. Julius Röhl, a foreign botanist, made extensive collections of mosses in America, in 1888, and many species of bryophytes collected in and near Hobart, Indiana, were published in his list in *Hedwigia* in 1893. Röhl's collections of American mosses are in the Botanisches Museum, Berlin-Dahlem, Germany.

Prof. Joseph P. Naylor,⁷ Head of the Physics Department of DePauw University for many years, was intensely interested in mosses, especially

⁵Born at Madison, Indiana, Sept. 7, 1858; died in Chicago, Feb. 24, 1910. Anonymous, 1910. Charles Reid Barnes. Bot. Gaz. 49:321-324. Cowles, Henry C., 1910. Charles Reid Barnes. Science 31:(no. 797) 532-533.

⁶Born at LeRoy, New York, Dec. 1, 1833; died in Chicago, Ill., Jan. 22, 1917. Chase, Agnes, 1917. Rev. E. J. Hill. Rhodora 19:60-69.

⁷Born in Pennsville, Ohio, April 4, 1853; died in Little Rock, Arkansas, May 22, 1938. Edington, Will E., 1939. Joseph P. Naylor. Proc. Ind. Acad. Sci. 48:6-7.

those of Putnam county. Upon retiring from his college teaching, he presented his herbarium of several hundred packets and his bryophyte library of many volumes to the Botany Department of DePauw.

The bryophytes collected in Monroe county, Indiana, 1912-1914, by Prof. F. L. Pickett and Mrs. Mildred Nothnagel Wilson are in the Herbarium of Indiana University and in the personal collections of Prof. Pickett, Pullman, Washington, and Mrs. Wilson, Iowa City, Iowa.

Many of the contributions to Indiana bryology have been made in county studies as Jefferson, Wayne, Putnam, Steuben, Monroe, Hamilton, Marion, etc., or in specific localities as Spring Mill Park and the Dunes. Prof. Underwood, in 1894, presented to the Academy of Science the "List of cryptogams at present known to inhabit the state of Indiana."

A review of the bibliography of Indiana bryophytes shows that the studies first made were lists of species and varieties collected, with habitat notations; these were succeeded by morphological and physiological projects; and within the last few years many ecological problems have been carried on, contributing to the bryophytes more scientific importance than they have ever before received.

As a member of the Biological Survey Committee of the Indiana Academy of Science for several years, I have prepared a bibliography of Indiana bryophytes in addition to making extensive collections of mosses and liverworts of the state. In order that this bibliography may be available to others interested in bryophyte studies, I am including in this history of Indiana bryology a bibliography of Indiana bryophytes consisting of 81 references.

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The Centraalbureau voor Schimmelcultures of Baarn, Netherlands

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Since the middle of the nineteenth century when the science of plant pathology was born, the interest in the knowledge of fungi and the application of that knowledge to the control of plant diseases and to industrial applications has increased tremendously. The increasing amount of attention that is being given to mycology is evidenced by the rapidly growing volume of literature on the subject. This interest is not a local one but is world-wide, and every country of the world can boast its mycological experts.

Every institution in which fungi are objects of study carry a variable number of cultures. A few of the larger universities in the United States put these cultures in the hands of trained experts, but, in the majority of our institutions, the care of fungus cultures rests in the hands of poorly trained assistants or staff members, who have little time to give the critical attention which such organisms need if they are to retain their morphological characters, physiological potentialities, or even their viability. In such instances, in which the care is adequate, the number of fungi in culture are usually limited to those typical species that are used in classroom work or to other species that happen to be the objects of investigational research.

Every worker with fungi has realized the importance of established centers where any fungus might be obtained within a reasonable length of time and where he could expect such fungi to be cared for in such a reliable manner that their purity and viability would not be questioned. Such a center should be a repository also in which new strains or species or even new and interesting isolations of old species might be sent and maintained. Furthermore, an establishment of this sort would be of service in the verification of fungus species.

Though the United States has a large percentage of the active mycologists of the world, we do not have such a center for the care of fungus cultures as I have described.

The American Type Culture collection, now housed in the Georgetown University Medical School, Washington, D. C., offers to the mycologist the best service available in this country. Many species and strains of fungi are listed in this collection, and I can testify from personal experience that the cultures received from the American Type Culture collection are quite satisfactory. This collection, however, is primarily of interest to the bacteriologist and to the medical student, and the list is not as complete nor the service so all-embracing as it should be in order to interest the mycologist. Furthermore, the fungi that are listed have had their origin largely in this country among our own research workers. In no sense, may the American Type Culture collection be considered "international" in scope. These same criticisms

apply also to other but less ambitious collections of fungi extant in the United States.

There has been an advertisement carried in *Phytopathology* at intermittent intervals for the past several years, describing the services offered by the *Centraalbureau voor Schimmelcultures* at Baarn, Holland. Our scientific journals have carried brief notes concerning the work of this bureau and the collection maintained there, and the necessity for its support has been mentioned at some of the business meetings of the American Phytopathological Society.

Such meagre accounts as were available have always stimulated an interest because I was aware of the need of such a bureau. Last year when I was abroad on Sabbatical leave from Purdue, I determined that the *Centraalbureau* at Baarn should be one of my objectives. I, therefore, wrote to Dr. Joh. Westerdijk, requesting permission to visit her laboratories and to inspect the work of the Bureau. This request was graciously granted.

The Willie Commelin Scholten Phytopathological laboratory was founded in 1894 by Mr. and Mrs. Scholten Commelin, in honor of their son Willie, a student of biology, who died in 1894. This institute had a threefold purpose: (1) to give information in the practice of agriculture, horticulture and forestry, about diseases and their prevention; (2) to increase knowledge of plant diseases by research-work; (3) to promote the interests in instruction in phytopathology.

This laboratory was established in Amsterdam. In 1905, the government withdrew its financial support. In 1906, Dr. Johanna Westerdijk was appointed director of the laboratory, and, in 1917, she was appointed also Professor of Phytopathology at the University of Utrecht. Much of the practical work in plant pathology was done by Dr. Westerdijk's students in the laboratory of the Institute in Amsterdam. This laboratory soon became overcrowded. The congestion was relieved by an unexpected gift. Mr. A. Janssen, a retired tea planter, lived at Baarn, 13 miles from Utrecht. In the neighborhood of his mansion, Canton-Hall, he bought a plot of ground on which he had constructed conservatories and a gardener's lodge and laid out ornamental gardens with pinetum, kitchen garden, and orchard. In 1920, after the death of Janssen, this entire property was offered to the State of the Netherlands to be used in botanical instruction in the University of Utrecht. The former kitchen garden and the orchard are used for instruction in plant pathology by Dr. Westerdijk. The Willie Commelin Scholten Institute purchased a country house with grounds in the immediate neighborhood of Cantons-Park and removed from Amsterdam to Baarn in 1920. Dr. Westerdijk also retains a professorship in the University of Amsterdam. The Institute has become a center for investigational work by graduate students of the various universities of the Netherlands, as well as for occasional foreign students.

The *Centraal Bureau* for fungus cultures has been allotted space in the laboratories of the Willie Commelin Scholten Institute at Baarn.

The history of the Bureau began in 1905, at which time the *Association Internationale des Botanistes* decided to bring together a collection of pure cultures of fungi. Dr. Westerdijk eventually became director of

the collection. During the first World War, the International Association of Botanists ceased to exist. In order to provide funds to keep the collection in existence, several Dutch Scientific Societies provided the necessary funds. In 1918, the Royal Academy of Sciences in Amsterdam succeeded in obtaining a regular grant of money from the government for the Centraal Bureau. This academy also furnished support by issuing necessary publications, including the annual "list of fungi". The Bureau is also supported by the Section botanique of the Union internationale des Sciences biologiques. These various avenues of financial support are not sufficient to maintain the collection, and additional funds must be sought by the sale of cultures.

At the present time, a staff of four scientific workers is engaged in maintaining and extending the collection. One of these is constantly transferring and inserting newly obtained fungi; the other three have specialized in various groups of fungi. New species are regularly being published. The yeasts are being monographed, and other groups will be monographed as time and funds permit. A complete case record is kept of each fungus from the time it is received, and notations are made for each transfer. These records are filed. When a fungus is received, it is cultured to determine the purity of species, and a complete description of the fungus with sketches of spores and fruiting structures is kept as a part of the record. Before a culture is sent to a subscriber, it is first transferred and tested for purity by comparing it to the original descriptions. If for any reason a culture loses its viability or becomes atypical, it is discarded, but its record card is kept although transferred to another file.

The total number of cultures at the beginning of 1939 was 6,394. This number is increased each year by 400 to 500. Of course, a few are lost, but the total continues to increase annually. As the number of cultures carried by the Bureau increases, the value of this service to mycologists likewise increases. It must be apparent that the burden of expense also mounts. Additional room is required with this expansion. More expert assistance must be employed. An increased budget for media, glassware, and equipment is demanded. The available funds do not increase. The donations by the Dutch Scientific Societies and by the government of the Netherlands is probably now at a maximum. In fact, such sources of income will probably be less in the next few years because of the confused political situation in Europe.

The facts that have thus been presented would indicate that the continued usefulness of the Bureau is threatened unless mycologists everywhere and especially in the United States give it more effective support.

This support should come by seeing to it that the institutions to which we belong become subscribers to the collection.

A subscription of 60 guilders, about \$33.00, entitles the organization subscribing to 50 cultures a year to be chosen from their printed lists.

A subscription of 30 guilders a year entitles one to select 20 cultures annually.

Cultures may be purchased individually without subscription at

the rate of two and one-half guilders per culture. Identifications are made for the same price.

Mycologists and plant pathologists may receive any culture in the list in exchange for one that they send which is not included in the published list.

Persons paying five guilders a year are considered to be donors.

The interest that is shown in fungi in this country, as may be indicated by the vast amount of published research, should cause mycologists to support eagerly the only elaborate clearing house for fungus cultures that is in existence.

Notes on Indiana Grasses, 1938, 1939

J. E. POTZGER, Butler University, and CHAS. M. EK, Kokomo

This is the seventh contribution of a series of annual reports on Indiana grasses previously unreported for the counties specified.

The nomenclature is that of Hitchcock's Manual of Grasses of the United States, 1935. The figures are J. E. Potzger's field numbers. Collections made by Ray C. Friesner are starred. All reports for Howard and Miami counties were made by Chas. M. Ek. A specimen of each grass reported here was deposited in the herbarium of Butler University.

Aegilops cylindrica Host., Howard (first report for the state).
Agropyron pauciflorum (Schwein) Hitchc., Howard. *Agropyron repens* (L.) Beauv., Howard, Tipton, 8135. *Agropyron Smithii* Rydb., Howard, Miami, Tipton, *10650, Steuben, 7964. *Agrostis alba* L., Howard. *Agrostis hiemalis* (Walter) B.S.P., Bartholomew, *10581, Howard, Switzerland, 7936. *Andropogon furcatus* Muhl., Howard. *Andropogon scoparius* Michaux, Howard. *Aristida longespica* Poiret, Howard. *Aristida oligantha* Michaux, Howard. *Aristida purpurascens* Poiret, Clinton, 8265. *Brachyelytrum erectum* (Schreber) Beauv., Howard. *Bromus commutatus* Schrad., Grant, *10961, Howard, Switzerland, 7928, Warren, *11105. *Bromus inermis* Leysser, Fulton, 8149. *Bromus latiglumis* (Shear.) Hitchc., Howard. *Bromus japonicus* Thunberg, Howard. *Bromus purgans* L., Steuben, 7969, Warren, *11103. *Bromus secalinus* L., Howard, Ripley, 7919, Switzerland, 7938, Warren, *10969, Fulton, 8150. *Bromus tectorum* L., Warren, *10994. *Calamagrostis canadensis* (Michaux) Beauv., Grant, *10806, Hamilton, *10618, Howard, Miami, Tipton, *10639. *Cenchrus pauciflorus* Benthams, Howard. *Cinna arundinacea* L., Howard. *Cynodon Dactylon* (L.) Persoon, Howard, 8263. *Dactylis glomerata* L., Howard, Switzerland, 7926. *Danthonia spicata* (L.) Beauv., Howard, St. Joseph, 8158. *Diarrhena americana* Beauv., Howard. *Digitaria Ischaemum* Schreber, Howard, 8256. *Digitaria sanguinalis* (L.) Scopoli, Howard, Kosciusko, 8249, Tipton, *11713. *Echinochloa crusgalli* (L.) Beauv., Howard. *Eleusine indica* (L.) Gaertner, Howard, Miami, Tipton, *11739. *Elymus canadensis* L., Howard. *Elymus riparius* Wiegand, Howard, Miami. *Elymus villosus* Muhl., Switzerland, 7941. *Elymus virginicus* L., Howard, Jackson, *11685. *Eragrostis cilianensis* (Allioni) Link, Howard, 8260, Miami, Tipton, *11737. *Eragrostis frankii* Steudel, Kosciusko, 8242. *Eragrostis hypnoides* (Lamarck) B.S.P., Howard, 8266, Miami, 8267. *Eragrostis pectinacea* (Mx.) Nees, Howard, 8262, Tipton, *11736. *Eragrostis spectabilis* (Pursh) Steudel, Howard, Newton, 8037. *Festuca elatior* L., Howard, Ripley, 7921, Switzerland, 7932. *Festuca obtusa* Sprengle, Howard. *Glyceria septentrionalis* Hitchc., Howard. *Glyceria striata* (Lam.) Hitchc., Grant, *10807, Howard, Warren, *11026. *Hordeum jubatum* L., Grant, *10836, Howard, Warren, *11037. *Hystrix patula* Moench, Howard, Warren, *11097. *Leersia oryzoides* Swartz, Howard, St. Joseph, 8237. *Leersia virginica* Willd., Howard, 8168. *Muhlenbergia foliosa* Trinius, Howard. *Muhlenbergia mexicana* (L.) Trin., How-

ard. *Muhlenbergia Schreberi* J. F. Gmelin, Howard, Dearborn, *11753. *Muhlenbergia sobolifera* (Muhlenberg) Trin., Tipton, *11694. *Muhlenbergia tenuiflora* (Willd.) B.S.P., Howard. *Panicum clandestinum* L., Howard. *Panicum dichotomum* L., Switzerland, 7924. *Panicum dichotomiflorum* Michaux, Howard. *Panicum Gattingeri*, Nash, Kosciusko, 8241. *Panicum huachucae* Ashe, Allen, 7958, Blackford, *10936, Fulton, 8146, Howard, Hamilton, *10621, Noble, 8007, St. Joseph, 8163, Switzerland, 7925, Warren, *11012, Wells, *10910. *Panicum latifolium*, Mx., Fulton, 8148, Howard, Warren, *11084. *Panicum leibergii* (Vasey) Scribn., Tipton, *10651. *Panicum lindheimeri* Nash, Cass, 7940. *Panicum linearifolium* Scribn., Bartholomew, *10577a, St. Joseph, 8159, Steuben, 7974, Warren, *11067. *Panicum sphaerocarpon* Ell., Steuben, 7987. *Panicum microcarpon* Muhl., Cass., 7940. *Panicum Scribnerianum* Nash, Howard. *Panicum spretum* Schult., Cass, 7947. *Panicum virgatum* L., Howard, 8279, Ripley, *11792. *Panicum Werneri* Scribn., Montgomery, 8133, Warren, *11067. *Phalaris arundinacea* L., Howard. *Phleum pratense* L., Howard, Ripley, 7920, Switzerland, 7934. *Poa annua* L., Howard. *Poa compressa* L., Allen, 7960. Switzerland, 7939, Warren, *11002. *Poa palustris* L., Howard, Steuben, 7976. *Poa pratensis* L., Switzerland, 7927. *Setaria Italica* (L.) Beauv., Howard. *Setaria lutescens* (Weigel) Hubbard, Howard. *Setaria verticillata* (L.) Beauv., Cass, Howard. *Setaria viridis* (L.) Beauv., Howard, Warren, *10970. *Sorghastrum nutans* (L.) Nash, Howard. *Sorghum halepense* (L.) Persoon, Howard, Ripley, *11785. *Spartina pectinata* Link, Howard, Miami. *Sporobolus asper* (Michaux) Kunth, Howard. *Sporobolus cryptandrus* (Torr.) A. Gray, Newton, 8048. *Sporobolus neglectus* Nash, Howard, Tipton, *11715. *Sporobolus vaginaeflorus* (Torr.) Wood, Howard, Tipton, *11735. *Triodia flava* (L.) Hitchc., Dearborn, *11773, Howard, 8273.

The Effect of Bacterial Contaminations Upon the Subsequent Growth of Fungi in the Same Medium

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The following investigation is the outgrowth of a laboratory accident. Using a Difco product, an assistant made a liter of potato dextrose agar. He failed to sterilize it immediately and permitted it to stand for 48 hours at room temperature in the unsterilized condition. When the medium was remembered eventually, it was found to be contaminated by a soft dirty white viscid bacterial growth that had developed on the surface at the point of contact between the medium and the glass of the flask.

Inasmuch as the medium was not to be used for any critical work, it was decided to sterilize it for thirty minutes and to use it in plates and tubes for the purpose of multiplying certain fungus cultures. Very much to our surprise, several species of fungi transferred to this contaminated, but sterilized medium, failed to grow.

We made an attempt to repeat the sequence of phenomena under controlled conditions. Since we had not anticipated that the bacterial contaminant would have any unusual powers, we had not isolated or saved it.

Potato dextrose agar was prepared according to the previous formula. The medium was permitted to stand unsterilized in cotton-stoppered flasks on laboratory shelves for 48 hours. At the conclusion of that period, a bacterial growth that seemed to be similar to the one in the previous accidental experiment appeared on the surface of the agar. As previously, this medium was sterilized for thirty minutes at fifteen pounds pressure. A liter of fresh uncontaminated potato dextrose agar was subjected to the same period of sterilization. The latter preparation was considered a check. Following the sterilization of the contaminated medium, the bacterial growth was no longer visible, and, since there was no subsequent growth of the contaminating organism, it was apparent that this agar was now sterile. The potato dextrose agar that had supported the bacterial growth was slightly darker and a trifle more cloudy than the check; otherwise, there was no apparent difference.

For the purpose of simplicity in the recording of results, the potato dextrose agar which was contaminated and then sterilized will be known as medium "A". The uncontaminated sterilized potato dextrose agar will be known as medium "B".

A transfer culture was made of the bacterial growth on medium "A" previous to sterilization and the organism was determined to be a member of the *B. subtilis* group. This organism was used as a 'staling' organism in all the subsequent experiments reported in this paper.

A series of plates was poured from each medium. The media were inoculated at the center of each plate with either *Diplodia zeae* or *Fusarium moniliforme*. Daily growth was indicated by ringing. Both

F. moniliforme and *D. zeae* covered the plates (90 mm. plates) of normal medium within 100 hours of inoculation, (Medium "B"). The growth made by *F. moniliforme* on medium "A", after the same amount of time had elapsed, was 20 mm., and, although the plates were permitted to stand until the agar had completely dried, no further growth was recorded. The total amount of growth made in medium "A" by *D. zeae* averaged a diameter measurement of only 8 mm. The growth made by both fungi on the uncontaminated medium was normal in every respect with a considerable development of aerial mycelium. The mycelial development in medium "A" exhibited few aerial hyphae and the individual hyphae were distorted, which is an indication of such sharp inhibition as is produced by staling.

In order to determine whether the bacterial contaminant was directly inhibitory to fungus growth, plates were poured with normal potato dextrose agar and inoculated in the center with either *F. moniliforme* or *D. zeae*. After an interval of 24 hours, in which time the fungus was well established on the medium, the bacterial contaminant was also planted near the periphery of the plate in which the fungus had begun growth. After another 24-hour interval, both fungus species exhibited the phenomena associated with inhibition and by 72 hours were sharply inhibited.

Cook¹ studied the results of fungi that succeeded each other in the same culture medium. He used a liquid synthetic medium, 'Cook's No. II liquid medium.' A mixture of this with a medium that had supported growth or a medium in which the fungus previously grown was made one of the constituents was used as test media. He also filtered out the fungus elements of growth, and this liquid was used instead of distilled water in making a new medium. On such media he grew a succession of fungi. In the medium made with the liquid from the filtered growth, he observed acceleration of growth. From this fact, Cook concluded that, if toxic substances were produced by fungus growth, they were not thermostable and were removed when the media were sterilized. He apparently ignored the fact that he was increasing the nutrient content of the medium by the methods that he used and that this increase might account for stimulated growth and might overcome the effect of any toxic inhibitory materials.

Our tests, which were repeated many times, indicate:

1. That a bacterial organism closely related to *B. subtilis* is capable of producing products in potato dextrose agar that are sharply inhibitory to both *Fusarium moniliforme* and *Diplodia zeae*.
2. That the materials so produced are stable to temperatures as high as 250°F. maintained over a period of 30 minutes.
3. That media that have been contaminated by certain bacterial organisms are incapable of supporting the normal development of some fungi. It is probably unsafe to use sterile media that have previously been contaminated in any critical studies with fungi.
4. Fungus-bacterial combinations are abnormal in probably every instance.

¹Cook, Melville T., 1924. Succession of fungi on culture media. Amer. Journ. Bot. 11:94-99.

A Study of Certain Viruses Pathogenic to the Tomato¹

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Fig. 1

Fig. 2

Fig. 1. Streak of tomato following artificial inoculation in greenhouse. Photographed March 2, 1916, at Lafayette, Indiana, by George Osner.

Fig. 2. Distortion and malformation of young leaves of tomato plant infected with virus A.

Introduction

Winterblight or streak has been recognized as a transmissible virus disease of tomato in Indiana since 1916, (Fig. 1). It occurs mostly on greenhouse tomatoes, appearing in the initial stages as a necrotic spotting of the leaves and necrotic streaking of young stems and petioles. The tips of shoots are frequently killed. Subsequent symptoms are conspicuous mottling, distortion and malformation of leaves that develop subsequent to the necrotic phase, and stunting of the plants. Once the disease starts in a greenhouse planting, it usually spreads rapidly. Crop loss is complete if the disease develops before the tomato plants have attained any size or set much fruit.

As has been repeatedly demonstrated, this disease may be produced by a combination of the virus of tobacco mosaic (Johnson's tobacco virus 1 (23)) and a virus present in all tubers of many American varieties of potatoes (Johnson's tobacco virus 5 (23)). As considered here, it is essentially a double-virus disease in which the two viruses act in com-

¹Based upon a thesis submitted by R. W. Samson to the Faculty of Purdue University in partial fulfillment of the requirements for the Degree of Doctor of Philosophy, June, 1932.

The writer wishes to acknowledge his indebtedness to Doctor M. W. Gardner for advice and assistance.

plementary fashion to cause a more destructive disease than either virus alone will produce. This property of complementary action has been used by the writer to separate a number of viruses into two opposing groups. Each member of one group is complementary to the potato virus so far as its streak-producing property is concerned. The tobacco mosaic virus is a typical example of this group. Each virus of the second group is complementary to the tobacco mosaic virus. The virus from apparently healthy plants of many old American potato varieties is a typical example. For convenience, the first group is referred to as the virus A group, and the second as the virus B group.

The purpose of this paper is to present references to the pertinent literature and a brief account of some studies by the writer on the symptoms, host range, and properties of two viruses of the B group involved in the tomato streak complex.

Literature on the Double-Virus or Streak Disease of Tomato

The earliest reference that the writer has found to tomato streak is apparently in Plowright's writings of 1887 (28). The following workers, listed in chronological order from 1888 to 1931, also report work on the streak or winter-blight disease: Galloway (11), Lodeman and Bailey (3), Selby (37), Clinton (7), Orton and McKinney (27), Howitt and Stone (18), Gardner and Kendrick (13), Gardner (12), Dickson (8), Johnson (21, 22), Vanterpool (43), Gardner and Kendrick (14), Blood



Fig. 3

Fig. 4

Fig. 3. Jimson weed plant 28 days after inoculation with virus B, showing sequence of vein-clearing on older leaves, transverse bands of mild chlorosis and vein-banding on next younger and still younger leaf tissues, respectively, and irregular mottling barely visible on the younger leaves.

Fig. 4. Jimson weed plant 17 days after inoculation with the Jimson weed strain of virus B, showing the more severe disease produced by this virus.

(5), Berkeley (4), Stover (39), J. Henderson Smith (17), Jarrett (19), Doolittle and Blood (9), Valteau and Johnson (40, 42).

Clinton (7) probably was first to report artificial transmission of the disease. Vanterpool (Dickson, 8) and Johnson (21, 22) demonstrated its duplex nature. Gardner and Kendrick (14) showed by inoculation tests that it is produced by a combination of the tobacco mosaic virus and the virus present in apparently healthy potato plants, namely the virus of Fernow's mosaic B (10) and herein designated as virus B.

The Virus A Group

The strain of tobacco mosaic used for most of these studies with references made as virus A exhibited the properties of Johnson's tobacco virus 1 (23) such as resistance to drying, ageing, heat, dilution, and chemicals and produced typical tobacco mosaic symptoms on tobacco (1, 15) and tomato (13), (Fig. 2). In addition, a number of viruses were collected in tomato fields which gave strikingly different symptoms when inoculated into tomato alone but which produced typical tomato streak when combined with a B virus. That there should be a number of viruses of the A type is evident from the work of Henderson Smith (16), Jarrett (19), and Valteau and Johnson (40).

The Virus B Group

The individual viruses of the B group are characterized by their complementary action in the production of tomato streak when combined with virus A. Two in particular are of concern here. The first is evidently the one which has been referred to by other workers as the mottle or ringspot virus (22), healthy potato virus (41), mosaic B (10), and latent virus (6). The symptoms produced on tomato by the virus used in most of the writer's experiments compare best with those described by Burnett and Jones (6) as produced by their latent potato virus. On tobacco it has produced symptoms most comparable with Johnson's mottle virus. On Jimson weed (Fig. 3) it produces symptoms most like those figured by Fernow for his mosaic B.

The second virus was originally collected from a wild Jimson weed. It is more virulent than the potato virus and is best distinguished from the latter by the much more severe disease it produces on Jimson weed (Fig. 4) and *Nicandra physalodes*. When combined with virus A, it produces typical streak, thus marking it as a virus of the B group.

Literature on the virus B group.—Many workers have transmitted or attempted to transmit potato virus diseases to tomato. The following papers may be mentioned: Johnson (22, 23), Quanjer (29), Schultz and Folsom (35), Olitsky and Northrop (26), Fernow (10), Vanterpool (43), E. M. Johnson (20), Valteau and Johnson (41), Koch (25), Burnett and Jones (6). The following viruses have been described from apparently healthy potatoes: Virus of mosaic B (Fernow), spot necrosis and ring-spot (Johnson), veinbanding and healthy potato (Valteau and Johnson), and latent and virulent latent (Burnett and Jones). Johnson's spot necrosis has been split into a mottle virus and an insect-transmitted virus by Koch. The veinbanding virus is probably the same as Koch's

insect-transmitted virus. Valteau and Johnson and Burnett and Jones were unable to produce streak in tomato by combining it with virus A. The ringspot virus is apparently the same as Valteau and Johnson's healthy potato virus and Burnett and Jones' virulent latent virus. All of the above viruses, except that of veinbanding, appear to have a factor in common which combines with virus A to produce streak in tomato. Fernow's description of his mosaic B and Johnson's description of his mottle virus appear to fit this common factor which is designated here as virus B.

Symptoms produced by virus B.—Goldstein (15) has described a series of leaf symptoms that appear consistently on tobacco plants inoculated with the tobacco mosaic virus. An analogous set of symptoms is produced by virus B on tomato, Jimson weed, and tobacco. They appear on Jimson weed (Fig. 3) as veinclearing on the older leaves, general chlorosis with green islands on next younger tissue, and veinbanding on still younger tissue. Each of these more or less transverse bands of symptoms grades into the other with no sharp line of demarcation. All leaves that develop subsequent to those that show the veinbanding show irregular chlorotic areas between the major veins. The same sequence of symptoms develops on tomato and tobacco plants infected with virus B but is not so obvious.

Susceptibility of species and varieties of the Solanaceae to virus B.—Virus B was inoculated into the following 20 species and varieties of the Solanaceae: *Browallia elata* L.; *Capsicum frutescens* L., var. *Cayenne*; *Datura stramonium* L., (Jimson weed); *Lycopersicon esculentum* Mill., var. *Greater Baltimore*; *Lycopersicon pimpinellifolium* Mill.; *Nicandra physalodes* (L.) Pers.; *Nicotiana glauca* Link and Otto, var. *longiflora*; *N. Sanderae* Sanders; *N. sylvestris* Spegaz, and Comes; *N. tabacum* L.; *Petunia hybrida* Vilm., vars. *Calif. Giant* and *Gen. Dodds*; *Physalis Alkekengi* L.; *P. pubescens* L.; *P. subglabrata* Mackenzie and Bush; *Solanum carolinense* L.; *S. Melongena* L., vars. *Black Beauty* and *Napolean*; *S. nigrum* L.; *P. pseudocapsicum* L.; *S. tuberosum* L. (seedlings). It was recovered in apparently unaltered form from nineteen of the twenty. *S. pseudocapsicum* was not infected.

Mottling was produced on all plants from which the virus was recovered except for certain potato seedlings which showed no symptoms. Necrosis was produced on *N. physalodes*, pepper, and certain potato seedlings. The virus was recoverable only from the necrotic lesions of potato seedlings showing no other symptoms. It was recovered readily from the necrotic lesions on cayenne pepper but only occasionally from other parts of such infected plants.

Properties of virus B.—Virus B remained infectious after storage for 87 days in Jimson weed juice in the refrigerator and for 47 days at room temperature. In one test, virus B in tomato juice was still infectious after dilution to 1:10,000 but not 1:100,000. The inoculum was applied to the test plants with the broken point of a small glass pipette. The virus withstood drying for 16 days in Jimson weed leaves but not for 18 months. It survived heating at 61°C. for ten minutes but not 70°C.

Symptoms produced by the Jimson weed strain of virus B.—The striking symptoms produced by the virus from Jimson weed on tomato, Jimson weed (Fig. 4), certain species of tobacco, and *Nicandra physalodes* and the fact that it combines with virus A to produce streak have made it of special interest. The sequence of development of symptoms produced by this virus is much the same as that for virus B from potato, but the ultimate effects of the virus are much more severe. Clearing of the veins on the older leaves is quickly followed by a necrosis of the cleared veins, with necrosis extending into the interveinal areas. The general chlorosis of the next younger tissue is quickly followed by extensive necrosis of this same zone, producing a burned or scorched effect. Marked interveinal chlorosis and veinbanding develop on the next younger leaves with some necrotic spotting and rugosity. All leaves that develop later than these are coarsely mottled and more or less cupped, puckered, or savoyed.

Host range and properties of the Jimson weed strain of virus B.—The Jimson weed virus was used for inoculation and recovered unchanged from the same series of solanaceous hosts as virus B. The severity of the disease produced on Jimson weed, *Nicandra physalodes* and *Nicotiana glauca*, in particular, served to differentiate it from virus B. The virus was infectious after 87 days storage in Jimson weed juice in the refrigerator and after 16 days drying in Jimson weed and tomato leaves. It withstood heating at 75°C. for ten minutes, being more resistant to heat than virus B, and was infectious at a dilution of 1:10,000 but not 1:100,000.

Separation of the Component Viruses of Tomato Streak

In the course of the limited host range studies with the three viruses of concern in this paper, it was found that certain hosts could be used to separate out the viruses present in the streak complex. Virus A could be recovered only from the necrotic lesions on Jimson weed and certain potato seedlings inoculated with this virus. It was recovered from necrotic lesions on inoculated Black Beauty eggplant (*Solanum melongena*) and only occasionally from non-necrotic parts. It could be recovered from most portions of infected pepper plants. The B virus, on the other hand, could be recovered from all parts of Jimson weed plants inoculated with these viruses and from symptomless or mottled parts of the potato seedlings used in the studies. It was found possible to recover either B virus from Jimson weed or potato seedlings inoculated with streak. Virus A could be recovered from pepper inoculated with streak. The entire streak complex was sometimes recovered from non-necrotic parts of both Black Beauty eggplant and pepper. It appears that virus A invades this eggplant less extensively than the B viruses and that the latter do not become systemic in pepper to the same extent as virus A.

Summary

A number of viruses or strains of viruses of the tobacco mosaic group occur on canning tomatoes in Indiana. This conclusion is based on symptoms produced by various collections of these viruses and by their

complementary action with the so-called healthy potato virus or virus B in the production of tomato streak. Likewise, it appears that there are a number of viruses and strains of the virus B group, two of which are described in some detail. The differences in the extent to which the viruses of these two groups invade Jimson weed, Black Beauty eggplant, certain potato seedlings or clones, and pepper provide a means of their separation from a streak complex. The variety of forms and relative abundance of these viruses as they occur in Indiana justify additional investigations now under way.

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New Agaricaceae of the Chicago Region

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In 1909, Moffatt (15) reported 210 species of Agaricaceae that were collected in the "Chicago Region" (an area of about 1800 square miles around Chicago, Illinois) over a period of several years. Graham (8, 9, 10) added to this list between 1927 and 1933. His additions increased the number of Agaricaceae to 256 species and varieties distributed among 47 genera. The writer, while collecting Agarics in 1935, chiefly near Evanston, Illinois, which is near Chicago, found 109 species and varieties. Of this number 41 have not been reported from the Chicago Region. The addition of the 41 reported here gives a total of 297 species and varieties distributed among 48 genera for the designated area.

The writer has tried to determine the correct authority for the name of each new species reported. As a guide he has used the International Rules of Botanical Nomenclature of 1930 (1). It has seemed better not to refer to any pre-Friesian author in the author citation. Moreover, he has spelled the specific names as they were first spelled when the species were described except in those cases where the specific name did not agree in gender with the generic name. In the case of those species of recent description, the author citation is the one used by Kauffman (14).

The specimens are in the herbarium of the writer.

The additions to the list of Agaricaceae of the Chicago Region are as follows: *Agaricus Rodmani* Peck, *Amanita bisporiger* Atkinson, *A. mappa* (Fries) Quélet (1872), *Amanitopsis parvicolvata* Peck, *Bolbitius fragilis* Fries (1836-1838), *Cantharellus cinnabarinus* Schweinitz, *Clitocybe odor* (Fries) Quélet (1872), *Coprinus ebulbosus* Peck, *C. lagopus* Fries (1836-1838), *C. quadrifidus* Peck, *C. radians* Fries (1836-1838), *C. stercoreus*¹ Fries (1836-1838), *Cortinarius semisanguineus* (Fries) Gillet (1874), *Hypholoma hydrophilum* Fries (1836-1838), *H. incertum* Peck, *H. incertum* var. *sylvestre* Kauffman (1918), *H. sublateralitium* (Fries) Quélet (1872)² var. *perplexum* Peck, *Lactarius camphoratus* Fries (1836-1838), *L. chrysorheus* Fries (1836-1838), *L. ligniotus* Fries 1857), *L. volemus* Fries (1836-1838),³ *Lepiota coerulescens* Peck, *Marasmius capillaris* Morgan, *M. delectans* Morgan, *M. glabellus* Peck, *M. glabellus* var. *bellipes* Morgan, *M. magnisporus* Murrill, *M. ramealis* Fries (1836-1838), *M. resinosus* (Peck) Saccardo, *M. scorodoni* Fries (1836-1838), *M. semihirritipes* Peck, *Panus rudis* Fries (1836-1838), *Pholiota unicolor* (Fries) Quélet (1872), *Pleurotus circinatus* (Fries) Gillet (1874),⁴ *P. fimbriatus* (Fries) Gillet (1874)⁵ var. *regularis* Kauffman, (1918), *Pluteus cervinus* (Fries) Quélet (1872) var. *albus* Peck,

¹Commonly spelled *C. stercorarius* Fries.

²This author citation was kindly furnished by Dr. Alexander H. Smith of the University of Michigan.

³Frequently called *Lactaria lantiflua* (L.) Burlingham.

Psilocybe arenulina Peck, *Russula chamaeleontina* Fries (1836-1838), *R. foetens* Fries (1836-1838), *R. fragilis* Fries (1836-1838), *R. sp.*¹

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¹This fungus best fitted the description of *Russula atropurpurea* Maire (ex. Kromb. non Peck) as given by Kauffman, but the writer was unable to determine the correct author citation. Dr. Gertrude S. Burlingham has informed the writer that Krombholz described a species in 1845 to which he gave the name *Aparicus (Russula) atropurpureus*. This was transferred to the genus *Russula* by Maire in 1910 as "*Russula atropurpurea* Kromb. Abb. d. Pilze 9:6, t. 74, f. 5-6; non Peck!" However, since Peck had already described an entirely distinct species in 1888 as *R. atropurpurea*, Maire's transfer of Krombholz's *A. atropurpureus* to the genus *Russula* cannot carry with it Krombholz's original specific name. It, therefore, seems quite likely that Krombholz's plant does not at present have a name. It is also possible, according to Dr. Burlingham, that Kauffman's *R. atropurpurea* is not Krombholz's plant but some other species. Because of these facts, it seemed better to refer to the fungus merely as *R. sp.*

Some Studies of the Genus *Elymus*

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The genus *Elymus*, commonly known as the rye grasses, includes many species in the northern hemisphere. Deam, in *Grasses of Indiana*, states that 25 species are found in the United States, chiefly in the western states.

The present study is not a taxonomic one but is directed rather towards the habits, reproduction, and chemical nature of the plant with a view to its possible economic value and modification in the direction of greater usefulness to man.

Elymus virginicus L. first came under observation in October, 1937. The original source of materials was a group of plants growing along the roadside in the Ohio river bottoms of Vanderburgh County, Indiana. This is a location frequently inundated at flood time. In November, 1937, *Elymus virginicus* var. *jejunus* (Ramaley) Bush. was collected on the top of Pilot Mountain near Ironton, Missouri, in the Ozark region.

Observation of these species shows that they are perennial. The new growth each year comes from buds at the lower nodes, which are frequently below the surface of the ground. Several new shoots develop from the base of each old culm so that the cluster tends to increase in size annually. One seed of variety *jejunus* germinated in the laboratory in February, 1938, produced a cluster of short culms in 1938 but produced no spikes. In 1939 the same plant with garden cultivation produced 147 fully developed spikes. The species observed will thus maintain themselves, tending to occupy the area more fully each year. These species do not produce rhizomes and show no tendencies which might make them objectionable because of being difficult to destroy, as is the case with some grasses such as the well-known quack grass.

Elymus matures slowly; it does not ripen in the sense that wheat does. In 1939 plants were in full bloom July 5; the spikes were harvested September 16. At this time some green still existed in leaves and culms, and some glumes were green. This occurred in a very dry season. In nature, seeds begin to fall from the plant about November 1 and continue to fall through most of the winter. Seeds lying on the ground were found germinating in February and by March were rooted. Experiments to determine most satisfactory planting time have not yet been completed.

The seed of the rye grasses is elongated in form, similar to those of the cultivated rye. It is usually dark in color. The lemma and palea are partially adherent to the seed and are removed with difficulty. Any threshing operation yields a product very similar in appearance to the cultivated oat.

A chemical analysis of the seeds of variety *jejunus*, after lemma and palea have been removed, gives the following protein content:

1938 crop	27.20% protein
1939 crop	27.22% protein

On the same basis of analysis other cultivated grain yields the following protein content:

	Mean	Range	
Rye ¹	12.4%	8.4%	19.%
Wheat ¹	12.2%	8.5%	17.%
Barley ²	11.5%	.....	.....
Oats ²	12.1%	9.1%	15.%
Corn ¹	10. %	.....	.....
Elymus ³	27.2%	.....	.....

In this analysis the total nitrogen in the sample is determined, and this figure, multiplied by a predetermined factor for cultivated rye, was used, since none is on record for *Elymus*. For this reason, it is probably preferable to compare the nitrogen findings for the grain.

Nitrogen content of cultivated grasses is as follows:

Rye ¹	1.98%
Wheat ¹	2.14 %
Barley ²	1.84%
Oats ²	1.93%
Corn ¹	1.60%
Elymus ³	4.845%

If *Elymus* is to have any economic value to man, the size of the seed is of great importance. Considerable variation has been noted. Twenty-seven seeds of *Elymus virginicus* were carefully weighed after removal of lemma and palea; these averaged .00263 gm. When the variety *jejunus* was found, its seed proved to be much larger. Fourteen seeds, weighed under identical conditions, averaged .00407 gm. This represents an increase of 54.7% over the earlier varieties studied.

In the spike of *Elymus* spikelets are borne in pairs lying close together. Glumes are long, narrow, and indurated. The spikelet contains two or three florets. One or two may mature, but the third seldom contains a seed. The spikelets may disarticulate either above or below the glumes in about equal numbers. Those florets that disarticulate from the glumes may be separated out quite well by sifting and fanning methods. Those which remain attached to the glumes are separated with great difficulty.

General observations indicate that *Elymus* is very drought resistant. Along the roadside in Kansas in August, 1939, it was quite well-developed although cultivated wheat had been almost a total failure and the corn crop had been destroyed by drought and hot winds.

In its present wild condition the grain of *Elymus* would scarcely be useful to man except in stock feed because of the adherent lemma and

¹Sherman, H. C., 1924. Food products. New York.

²David, W. A., and S. S. Sadler, 1917. Allen's commercial organic analysis. Philadelphia.

³Done by Department of Chemistry, Evansville College.

palea. If varieties with larger grain which can be separated from adhering coverings can be found or developed, it may find important uses.

Numerous new collections were made in August, 1939, in the states of Nebraska, Wyoming, Colorado, Kansas, and Missouri. These undoubtedly include several varieties. Hybridization has not yet been tried.

Notes on Some Indiana Plants

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Pteridium aquilinum (L.) Kuhn var. *pseudocaudatum* (Clute) Heller.—Peattie in his *Flora of the Indiana Dunes* lists *Pteridium latiusculum* var. *pseudocaudatum* as "sometimes found with the species in our area, acc. to Clute." This report is not known to be substantiated by a specimen, and, since numerous collectors have failed to find var. *pseudocaudatum* in the Dunes, it seems best to disregard it until authentic material is found.

However, on the Taxonomists' Field Trip this summer, characteristic specimens were collected on a sand hill along the C. & E. I. R. R., $\frac{1}{2}$ mile south of Emison, Knox Co. (Tryon 4268). Also, there is a specimen in the herbarium of Mr. C. C. Deam collected in 1913 in a wooded ravine 1 mile east of Taswell, Crawford Co. (Deam 13976). The ultimate segments are long, entire, and glabrous or glabrate. These are the northernmost stations in the Mississippi Valley. Besides its broad Coastal Plain range from Long Island, New York, to Texas, it occurs throughout the southern half of Missouri, and I have seen one specimen from Kentucky.

Convolvulus spithameus and *C. sepium*.—Following the author's recent treatment in *Rhodora* 41:415 (1939), the specimens of these two species in the herbarium of Mr. C. C. Deam have been identified as follows:

The descriptions have been drawn up from the Indiana material.

C. spithameus L. (typical)—Plant somewhat pubescent to glabrate, erect, short and compact, or sometimes tall, but the tip not prolonged; leaves tapering, rounded, auricled or sagittate at the base; basal leaves not more than one-half as long as some of the upper ones, often much reduced; petiole of the first leaf above the uppermost flower usually not more than one-fourth as long as the blade, rarely one-third as long; flowers white, usually 1-2, rarely 3-4.

Southwestern Quebec to Ontario and Minnesota, south to Iowa, Illinois, Kentucky, Pennsylvania, and Maryland, and in the mountains to West Virginia and Virginia.

INDIANA: Clark, Dearborn, Harrison, Lawrence, Noble, Porter, Steuben, Tippecanoe, Wells, and Whitley counties.

C. spithameus L. var. *Catesbeianus* (Pursh) Tryon—Plant fairly pubescent, tall, the tip prolonged; leaves sagittate; basal leaves small as in typical *spithameus*; petiole of the first leaf above the uppermost flower at least one-third as long as the blade; flowers white, 1-7.

Virginia to Georgia and Alabama; Indiana.

INDIANA: Crawford, Noble, Orange, Perry, and Pike counties.

The Indiana material is typical except that two specimens (Deam 24928, 7 flowers, Deam 35606, 6 flowers) have more flowers than I have seen before in this variety. However, typical *C. spithameus* may rarely

have as many as ten flowers (Greenbriar Co., West Virginia, Hunnewell 6701, Herb. Hunnewell), and so it may be expected that var. *Catesbeianus* would be equally variable in this character. Nevertheless, the specimens with many flowers look very much like *C. sepium* var. *repens* and can be referred here only because of their small basal leaves and the typical "spithamaeus" leaf-shape, which is very difficult to actually describe.

This is the first report for the state.

C. sepium L. var. *communis* Tryon—Plant essentially glabrous; leaves hastate, the basal lobes angled; flowers pink; peduncles usually exceeding the petioles but rarely the leaves.

Southern Quebec south to Virginia and sparingly to Florida, west to Minnesota, Oregon, and Washington.

INDIANA: Lake, Ripley, Vigo, and Whitley counties. A doubtful specimen from Allen county.

This is the first report for the state.

C. sepium L. var. *americanus* Sims—Plant essentially glabrous; leaves sagittate, the basal lobes rounded or slightly pointed; flowers pink; peduncles often exceeding the leaves.

Newfoundland, southern Quebec and Nova Scotia, south along the coast to Maryland and Virginia; also about the Great Lakes in Ontario, Ohio, Michigan, Indiana, Wisconsin, and Minnesota.

INDIANA: Lagrange, Laporte, Kosciusko, and Steuben counties. A doubtful specimen from Miami county.

First report for the state in *Rhodora* 41:415 (1939).

C. sepium L. var. *repens* (L.) Gray—Plant pubescent to essentially glabrous; leaves sagittate or sometimes hastate, the basal lobes usually rounded, sometimes the leaf sagittate and the lobes angled, leaf-blade characteristically long and narrow; flowers white or white with a pink margin; peduncles not exceeding the leaves.

Rhode Island to Florida, Louisiana and Missouri on the Coastal Plain; in the mountains of West Virginia; scattered in Indiana, not confined to the areas in which typical Coastal Plain plants are usually found.

INDIANA: Bartholomew, Brown, Carroll, Clay, Dearborn, Greene, Hamilton, Hancock, Harrison, Hendricks, Montgomery, Perry, Putnam, Shelby, Spencer, Tipton, Vermillion, Wells, and White counties.

Although the specimens in the Gray Herbarium indicate that var. *repens* has a typical Coastal Plain range, its distribution in Indiana is not that of a typical Coastal Plain plant.

C. sepium L. var. *fraterniflorus* (Mack. & Bush) Mack. & Bush—Plant pubescent to essentially glabrous; leaves hastate, the basal lobes angled; flowers white; peduncles usually exceeding the petioles but rarely the leaves.

Indiana to Montana, south to Arkansas and New Mexico.

INDIANA: Adams, Allen, Floyd, Greene, Knox, Owen, Posey, Warlick and Wells counties. A doubtful specimen from Benton county.

A Titrimetric Method for the Determination of Nicotine in Tobacco Tissues

RAY F. DAWSON, DePauw University

A great many accurate and valuable methods have been developed for the quantitative estimation of nicotine in samples of tobacco tissue. The procedure most generally employed is that recommended by the Association of Official Agricultural Chemists in which nicotine is precipitated as the silicotungstate from a steam distillate of the tobacco tissues. This method is time-consuming, however, and requires careful temperature control during the ashing process. A new method has been devised which permits the rapid separation of nicotine from the remainder of the volatile bases which pass over with nicotine during the steam distillation. In its principal features, this method combines the steam distillation portion of the official method¹ with the ammonia distillation procedure described by Vickery and his associates.²

At ordinary pressures nicotine passes quantitatively into the vapor phase when steam is passed through its aqueous solution. In this state it is generally associated with ammonia and with small amounts of unknown bases. The vapor phase, when passed into standard acid, loses its basic constituents which, consequently, may be determined by direct titration with alkali. Since nicotine is nearly as strong a base as sodium hydroxide, it titrates quite readily. Under reduced pressure and at the boiling point of water, ammonia and the remainder of the lower boiling bases pass from the aqueous phase into the vapor phase; nicotine remains behind. The former may be trapped in standard acid and again titrated. The nicotine equivalent of the difference between the two titrations may then be calculated. If a positive determination is desired, the nicotine may be redistilled from the residues and titrated directly.

The advantages of the method are the rapidity with which individual analyses may be completed and its ease of application to semi-micro procedures. If suitable apparatus is available, duplicate determinations may be completed parallel with one another in a period of one hour or less. Furthermore, samples of tissue weighing 0.20 gm. may be employed, provided the volume of the distillation system is sufficiently small. Duplicate determinations usually check within 3% or less of one another. Very frequently the agreement is exact. Repeated tests have shown that, under the conditions prescribed for the conduction of the vacuum distillation, nicotine is not volatilized in sufficient amounts to be detected by qualitative reagents such as silicotungstic and picric acids even when the distillate is concentrated to a small volume. When compared with the usual silicotungstic acid quantitative method, the

¹Official and tentative methods of analysis of the association of official agricultural chemists, 1935. Fourth ed. P. 60.

²Pucher, G. W., H. B. Vickery, and C. S. Leavenworth, 1935. *Ind. Eng. Chem., Anal. Ed.* 7:152.

new procedure gives results which are in reasonable agreement. In Table I are listed the results of a few repetitive and comparative analyses in which the new method has been employed.

TABLE I.—Percentage of Nicotine in Dry Tobacco Samples by Titrimetric Method and by Gravimetric Method

Sample	Titrimetric Method	Gravimetric Method
	Percentage	Percentage
1.....	9.57	
	9.49	
2.....	3.96	
	3.94	
3.....	0.90	
	0.90	
4.....	0.24	
	0.25	
5.....	9.50	9.72
6.....	5.85	5.98
7.....	0.63	0.65
8.....	0.42	0.40

Since the new method represents merely the combination of two procedures which have been described very thoroughly elsewhere in the literature^{1,2}, a brief outline of its adaptation to semi-micro analysis will be included here.

The Titrimetric Method

The sample of dry, finely powdered tissue is well mixed, and 0.20 gm. of the powder is transferred from a weighing bottle to a 125 cc. Erlenmeyer flask and suspended in 20 cc. of water. If an aqueous extract of tobacco tissues is employed, the aliquot to be used for analysis should contain not less than 0.5 mgm. of nicotine. Three drops of paraffin oil and 0.2 cc. of a concentrated nitrogen free solution of sodium hydroxide are added, and the flask is attached to a steam distillation apparatus. The receiver should be charged with an appropriate volume of 0.0200 N HCl delivered from a micro burette which is calibrated in units of 0.02 cc. Distillation is continued with bottom heat until about 50-75 cc. of distillate are collected, depending upon the nicotine content of the tissues. Titration to the end-point of a methyl red-methylene blue indicator yields the total volatile base content of the tissues.

The distillate is then quantitatively transferred to a 200 cc. round bottom flask, and a few drops of a sodium hydroxide-sodium borate solution (5 gm. of borax dissolved in 100 cc. of 0.5 N nitrogen free sodium hydroxide)' are added. Standard acid is placed in the suction flask-

receiver, and the vacuum pump is turned on while the nicotine solution is still at room temperature. When the solution begins to discharge its dissolved gases vigorously, a water bath previously warmed to 42°C. is raised around the flask and distillation continued for 20 minutes. At the end of this time, the water bath is lowered, the vacuum released very slowly, the suction flask removed from the apparatus, and the distillate titrated as before. The difference between the two titrations corrected for the apparatus blank (usually between 0.02 and 0.04 cc. of 0.0200 *N* acid) and multiplied by the nicotine equivalent of the standard acid yields the quantity of nicotine contained in the sample of tissue.

The author is indebted to the National Research Council for financial assistance and to Professor S. F. Trelease of the Department of Botany of Columbia University and Dr. H. B. Vickery of the Connecticut Agricultural Experiment Station for generous contributions of their time and laboratory facilities in the completion of this and related researches.

CHEMISTRY

Chairman: H. T. BRISCOE, Indiana University

The address of Chairman H. T. Briscoe on Two Decades in the History of Chemistry and the paper on The Preparation of Acetyl Bromide, by M. T. Bruton and Ed. F. Degering, are published by title only.

Karl Means, Butler University, was elected chairman for 1940.

The Adsorption of Potassium Ferrocyanide and Ferric Sulfate by Prussian Blue

E. W. KANNING and A. W. CAMPBELL, Indiana University

Studies concerning the composition of Prussian blue precipitates formed by the interaction of the ferric and ferrocyanide ions have led to interesting and, in some instances, conflicting conclusions. It has been shown that, when the reactants are mixed, oxidation-reduction reactions and adsorption occur which prevent the formation of the stoichiometric compound, $\text{Fe}_3[\text{Fe}(\text{CN})_6]_x$. Bhattacharya and Dhar¹ report experiments that indicate that this compound is formed when a solution of ferric chloride is added to a solution of potassium ferrocyanide. They further point out that, when the precipitate is allowed to age in contact with the supernatant liquid, the composition of the precipitate changes to approach an equilibrium mixture as a result of either oxidation-reduction or adsorption processes or both. It is pointed out that Prussian blue is primarily susceptible to adsorption processes.

The simple compound, $\text{Fe}_3[\text{Fe}(\text{CN})_6]_x$, is formed, according to Müller,² only if the solutions of ferric iron and ferrocyanide are of definite concentrations. In most cases the precipitate consists of a complex mixture, the exact composition of which depends upon the conditions under which it is prepared. Woringer³ states that commercial iron blue is a complex compound, $\text{Fe}^{III}\text{Fe}^{II}_x[\text{Fe}_3(\text{CN})_6]_x$, which is formed as the result of the mutual oxidation and reduction of the ferric and ferrocyanide ions. Schmidt and Rassow⁴ are of the opinion that Prussian blue is a ferric ferrocyanide in which part of the iron is replaced by potassium and two molecules of water in intermolecular combination. Davidson and Welo⁵ state that the formulas for the "soluble" and "insoluble" blues are $\text{KFe}[\text{Fe}(\text{CN})_6]$ and $\text{Fe}_3[\text{Fe}(\text{CN})_6]_x$, respectively. Justin-Mueller⁶ suggests the formula, $\text{Fe}^{III}[\text{Fe}^{II} : (\text{CN})_6 : \text{Fe}^{III}]_x$.

¹Bhattacharya, A., and Dhar, N. R., *Z. für anorg. und allgem. Chem.*, **213**:240-8 (1933).

²Müller, E., *Journ. prakt. Chem.*, **84**:353-69 (1911).

³Woringer, P., *Chem.-Ztg.*, **36**:78 (1912).

⁴Schmidt, P. F., and Rassow, B., *Z. Angew. Chem.*, **37**:338-4 (1924).

⁵Davidson, D., and Welo, L. A., *Journ. Phys. Chem.*, **32**:1285-9 (1931).

⁶Justin-Mueller, E., *Bull. Soc. Chim.*, **49**:1285-9 (1931).

From experiments carried out by Ihne and Kanning⁷ concerning the composition of iron blue, it was concluded that Prussian blue prepared by the oxidation of the so-called "white paste" (primarily ferrous ferrocyanide with adsorbed alkali ferrocyanide) consists of ferric ferrocyanide in combination with the alkali ferrocyanide as an adsorption product. The extent of the adsorption of the soluble ferrocyanide was found to depend upon the relative concentrations and proportions of the ferrous and ferrocyanide ions used in the preparation of the ferrous ferrocyanide.

The experiments reported in this paper are for the purpose of determining quantitatively the adsorptive capacity of Prussian blue for potassium ferrocyanide and ferric chloride in an effort to add to the already existing data concerning the fact that Prussian blue, when prepared, contains contaminating substances as adsorption products. The adsorption experiments were performed on Prussian blue precipitates, prepared and dried in a specific manner. The effect of ageing the prepared precipitate was also studied.

Experimental

Preparation of the Prussian blue precipitates.—The Prussian blue was prepared by adding 2,625 ml. of 2N ferric sulfate solution to 2,500 ml. of 2N potassium ferrocyanide solution. The mixture was stirred thoroughly and divided into two equal parts.

One part of the mixture was filtered with suction, washed free of soluble ions and dried at a temperature of 95°C. for 50 hours. The dried Prussian blue was then pulverized and again dried for 95 hours at 95°C. This product was ground in an agate mortar until it passed a 100 mesh sieve and is designated "fresh" Prussian blue.

The second portion of the precipitated Prussian blue was transferred to a large flask and maintained at a temperature of 98°C. for 240 hours. After this "ageing" process, the precipitate was filtered, washed, dried, and pulverized in the same manner as was the first portion. This particular sample was designated "aged" Prussian blue.

Determination of adsorptive capacities of the Prussian blues.—The capacity of each of the two Prussian blues for adsorbing potassium ferrocyanide and ferric sulfate was determined at varying concentrations of the adsorbate. The procedure employed for the adsorption determinations was the same in each instance.

A sample of the powdered Prussian blue, weighing 10.000 gm. was placed in 100 ml. of the solution of the adsorbate contained in a 125 ml. Erlenmeyer flask which had previously been immersed in a constant temperature bath at 25°C. The flask was then stoppered, shaken vigorously, and replaced in the constant temperature bath for 30 minutes. During this time, the contents of the flask were thoroughly mixed by shaking every five minutes. As is customary, adsorption equilibrium was assumed to be attained after 30 minutes.

When adsorption was complete, the contents of the flask were passed through a parlodion ultrafilter which served to separate well

⁷Ihne, R. E., and Kanning, E. W., *Ind. Eng. Chem.*, 31:88-9 (1939).

the Prussian blue from the solution of the adsorbate. The concentration of the filtrate from the ultrafiltration process was then determined which, when subtracted from the concentration before adsorption, yielded data from which the extent of the adsorption was calculated. Both the ferric and ferrocyanide ions were determined by titration in acid solution with potassium permanganate.

In order to avoid errors due to the dilution of the filtrate by water retained by the ultrafilter in its preparation or to the adsorption of ferric or ferrocyanide ions by the ultrafilter material, blank determinations were carried out. It was found that no change in concentration of the adsorbate solutions occurred when passed through the ultrafilter. It was also found by actual test that no detectable quantity of Prussian blue would pass the ultrafilter.

Data and Results

The results obtained for the adsorption of potassium ferrocyanide by the "fresh" Prussian blue are presented in Table I. The extent of adsorption is represented by the values of X/M and is expressed as milli-equivalents of potassium ferrocyanide adsorbed per gram of Prussian blue. The table also includes the logarithms of the factors, C , and X/M , where C is the final concentration of adsorbate. The data in Table II shows the adsorption of ferric sulfate by the "fresh" Prussian blue. The curves in Fig. 1 are the graphical representations of the adsorption of potassium ferrocyanide (curve I) and ferric sulfate (curve II) by the "fresh" Prussian blue. The curves are obtained by plotting the values of X/M as ordinates and the final adsorbate concentration, C , as abscissae. The logarithm curves, obtained by plotting $\log C$ and $\log X/M$ are presented in Fig. 3, in which curve I represents the adsorption of the ferrocyanide and curve II the adsorption of ferric sulfate.

The results obtained for the adsorption of potassium ferrocyanide and ferric sulfate by the "aged" Prussian blue are presented in Tables III and IV, respectively. The adsorption curves for the "aged" sample

TABLE I.—Adsorption of Potassium Ferrocyanide by "Fresh" Prussian Blue

Initial Conc. of $K_4Fe(CN)_6$ (g.eq./l)	Final Conc. of $K_4Fe(CN)_6$ (g.eq./l) (C)	Log C	X/M	Log X/M
3.020	2.300	0.362	7.20	0.847
1.924	1.302	0.115	6.22	0.793
1.000	0.517	-0.287	4.83	0.684
0.500	0.117	-0.937	3.83	0.583
0.252	0.010	-2.000	2.42	0.384
0.1124	0.0012	-2.921	1.21	0.083
0.0504	0.0016	-2.796	0.488	-0.312

TABLE II.—Adsorption of Ferric Sulfate by "Fresh" Prussian Blue

Initial Conc. of $\text{Fe}_2(\text{SO}_4)_3$ (g.eq./l)	Final Conc. of $\text{Fe}_2(\text{SO}_4)_3$ (g.eq./l) (C)	log C	X/M	Log X/M
2.76	2.663	0.0425	0.975	-0.011
1.93	1.863	0.270	0.705	-0.152
1.0125	0.969	-0.014	0.435	-0.362
1.011	0.960	-0.018	0.510	-0.292
0.5055	0.485	-0.315	0.210	-0.678
0.249	0.237	-0.625	0.120	-0.921
0.1134	0.1014	-0.994	0.120	-0.921
0.0564	0.0444	-1.353	0.120	-0.921

TABLE III.—Adsorption of Potassium Ferrocyanide by "Aged" Prussian Blue

Initial Conc. of $\text{K}_4\text{Fe}(\text{CN})_6$ (g.eq./l)	Final Conc. of $\text{K}_4\text{Fe}(\text{CN})_6$ (g.eq./l) (C)	Log C	X/M	Log X/M
2.637	1.940	0.288	6.97	0.843
1.918	1.385	0.141	5.33	0.727
1.449	0.959	-0.018	4.90	0.690
0.999	0.639	-0.195	3.60	0.556
0.498	0.259	-0.587	2.39	0.378
0.260	0.1108	-0.955	1.50	0.176
0.0493	0.00012	-3.921	0.49	-0.310

of Prussian blue are shown in Fig. 2; curve III represents the adsorption of potassium ferrocyanide and curve IV the adsorption of ferric sulfate. The log curves for the adsorption experiments with the "aged" Prussian blue are shown in Fig. 3; curve III represents the log C-log X/M relation for potassium ferrocyanide and curve IV the corresponding relation for ferric sulfate.

Discussion of Results

From the data presented, it is apparent that positive adsorption from solution has occurred in all experiments. Both the "fresh" and the "aged" samples of Prussian blue possess a much greater adsorptive capacity for potassium ferrocyanide than for ferric sulfate. In Table I it is seen that, at an initial adsorbate concentration of 3.020 equivalents per liter, 1 gram of the adsorbent adsorbs 7.2 milli-equivalents or

TABLE IV.—Adsorption of Ferric Sulfate by "Aged" Prussian Blue

Initial Conc. of $\text{Fe}_2(\text{SO}_4)_3$ (g.eq./l)	Final Conc. of $\text{Fe}_2(\text{SO}_4)_3$ (g.eq./l) (C)	Log C	X/M	Log X/M
2.910	2.843	0.454	0.67	-0.174
2.433	2.375	0.375	0.60	-0.222
1.922	1.881	0.274	0.41	-0.387
1.415	1.382	0.141	0.33	-0.481
0.963	0.939	-0.027	0.24	-0.720
0.506	0.493	-0.307	0.13	-0.886
0.225	0.212	-0.674	0.13	-0.886

0.66 gm. of potassium ferrocyanide. The adsorption of ferric sulfate by the "fresh" Prussian blue was very slight, the maximum value of X/M being 0.975 milli-equivalents per gram of the adsorbent.

The adsorptive capacity of the "aged" sample of Prussian blue for the two salts studied was in general less at the same concentrations of adsorbate than that for the "fresh" sample. This difference in the adsorptive capacities of the two samples of the adsorbent can be seen by a comparison of curves I and II in Fig. 1 and curves III and IV in Fig. 2. The adsorptive capacity of the two samples of the Prussian blue for ferric sulfate is only slight; however, the adsorption of this salt by the "aged" adsorbent is slightly greater than that by the "fresh" sample. The data for the adsorption of ferric sulfate is considered subject to slight error because of the extremely small differences between the initial and final adsorbate concentrations.

Two explanations might serve to explain the effect of "ageing" the Prussian blue on its adsorptive capacity. The decreased capacity as a result of "ageing" at an elevated temperature could be due to a change in the physical nature of the adsorbent. The "ageing" process no doubt causes a general increased particle size, resulting in a decreased adsorbent surface. The effect of the "ageing" process by the formation, during the digestion period, of an equilibrium mixture of Prussian and Turnbull's blue has been suggested by experiments conducted by Bhattacharya and Dhar.¹ Turnbull's blue in general possesses less adsorptive capacity for the ferrocyanides, which would account for the effect of "ageing" of the precipitate studied. It is of interest to note (see curves I and II, Fig. 3) that the adsorptive capacity of the "fresh" Prussian blue exceeds that of the "aged" sample up to a potassium ferrocyanide concentration of about 2.0 N, beyond which the "aged" sample possesses the greater adsorptive capacity for this salt. It is difficult to explain this discrepancy.

The fact that adsorption has actually occurred in these experiments, especially in those involving the adsorption of potassium ferrocyanide, is evidenced by the nature of the curves that are obtained when the

concentration of the adsorbate is plotted against the quantity of adsorbate removed from solution. According to the adsorption equation, a parabolic curve should be obtained which yields a straight line when the logarithms of the coordinate factors are plotted. The curves in Figs. 1, 2, and 3 indicate that a process of adsorption is concerned in the removal of potassium ferrocyanide and ferric sulfate from solution by the two Prussian blues.

Summary

From the experiments performed, data are obtained that indicate a large adsorptive capacity of precipitated Prussian blue for potassium ferrocyanide and a comparatively small adsorptive capacity for ferric sulfate.

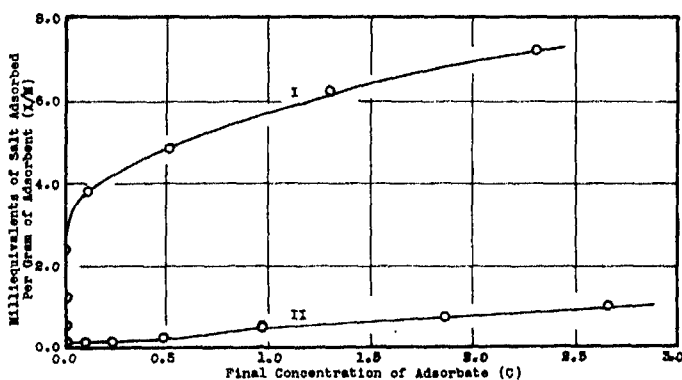


Fig. 1. Adsorption of potassium ferrocyanide and ferric sulfate by "fresh" Prussian blue. Curve I. Adsorption of potassium ferrocyanide. Curve II. Adsorption of ferric sulfate.

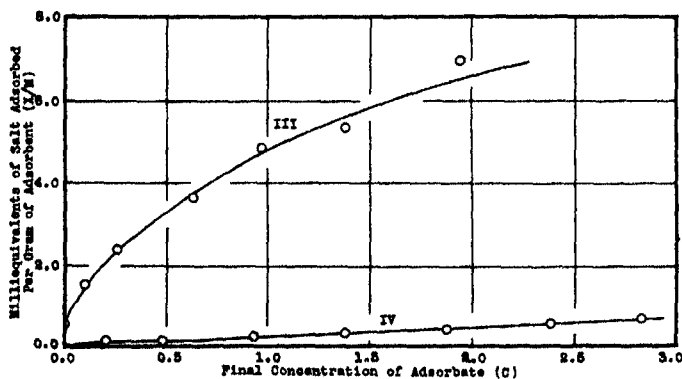


Fig. 2. Adsorption of potassium ferrocyanide and ferric sulfate by "aged" Prussian blue. Curve III. Adsorption of potassium ferrocyanide. Curve IV. Adsorption of ferric sulfate.

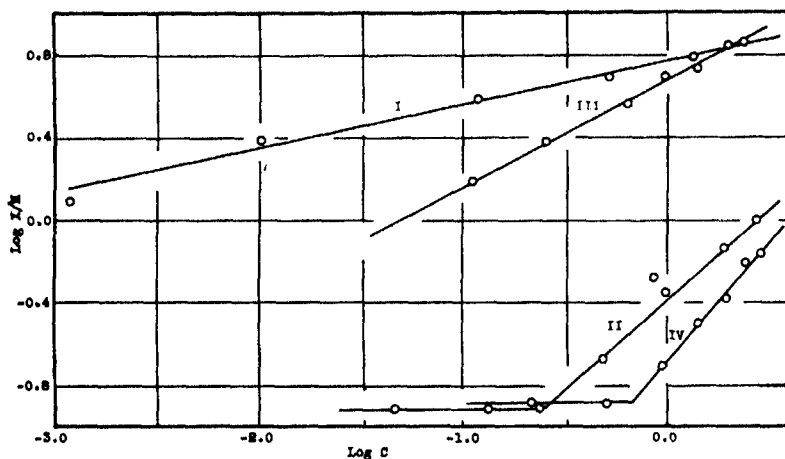


Fig. 3. Log X/M-log C relationship for the adsorption of potassium ferrocyanide and ferric sulfate by Prussian blue. Curves I and II. Adsorption of potassium ferrocyanide and ferric sulfate. Respectively by the "fresh" Prussian blue. Curves III and IV. Adsorption of potassium ferrocyanide and ferric sulfate. Respectively by the "aged" Prussian blue.

"Ageing" the precipitated Prussian blue for 240 hours at 98°C. produced an adsorbent which possessed a lesser adsorptive capacity for both potassium ferrocyanide and ferric sulfate.

The fact that the X/M-C curves follow the general form of the Freundlich adsorption isotherm is evidence that a true process of adsorption occurs in the removal of the two salts (potassium ferrocyanide and ferric sulfate) from solution by contact with dried Prussian blue.

The data presented in this and other papers seem to indicate that the explanation of the composition of precipitated Prussian blue should include the possible existence of the rather large quantities of soluble ferrocyanides and also small quantities of ferric salts adsorbed by the primary precipitate. Although the deviation of the composition of Prussian blue from the basic compound, $\text{Fe}_3[\text{Fe}(\text{CN})_6]_2$, may not be accounted for entirely on the basis of the adsorption of soluble salts by the primary precipitate, the process of adsorption seems to play a very important part in the definition of the composition of the product obtained from the interaction of ferrocyanide and ferric ions.

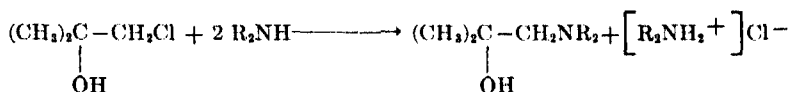
The Preparation of Amino Alcohols

KENNETH N. CAMPBELL and B. K. CAMPBELL, University of Notre Dame

Introduction

Since amino alcohols and their derivatives are of considerable importance as local anesthetics, their preparation has been the object of much attention. Three more or less general methods of preparation, as well as a host of minor ones, have been developed. In the first of these¹ the amino group is introduced into an ester, aldehyde, or ketone, and this amino compound is converted into an amino alcohol either by reduction or through the Grignard reaction. This method is very satisfactory in those cases where the amino alcohol can be readily isolated from aqueous solution and where the amino ester, aldehyde, or ketone is easily obtained and is stable. In the second method, which applies only to beta amino alcohols, the corresponding ethylene oxide is treated with ammonia or an amine.² This method is an excellent one but is limited by the availability of the ethylene oxides.

The third and most generally used reaction consists in treating the corresponding chloro (or bromo) hydrine with the desired amine, either at atmospheric pressure or in a sealed vessel, depending on the volatility of the reactants.³ Ammonia does not work as well as primary and secondary amines. Since hydrogen halide is formed in the reaction, it is necessary to remove it for the reaction to proceed.



Ordinarily, a second equivalent of amine is used for this purpose. This procedure has two main disadvantages. The yield of amino alcohol is apt to be low, especially in the case of the less basic, aromatic amines, and the procedure is an expensive one, particularly where the amine used is one of the higher, less readily available ones.

Since large amounts of amino alcohols were needed for work being conducted in this laboratory, a study was undertaken to determine whether inorganic bases could be substituted for the second equivalent of amine and, if so, to ascertain which inorganic bases were most suitable.⁴

Experimental Procedure

Reactions carried out at atmospheric pressure.—One-fourth of a mole of the chlorohydrine, one-fourth of a mole of the amine, and a

¹Mannich and Hof, 1927. *Arch. Pharm.* 265:589. Paul and Weidenkaff, 1906. *Ber.* 39:810.

²Krasausky, 1927. *Journ. prakt. Chem.* 115:322.

³Fourneau, 1904. *Compt. rend.* 138:766.

⁴The authors wish to thank Mr. Milton J. Eisert and Mr. William Long for doing part of the experimental work.

slight excess of the alkaline binding agent were mixed with the solvent. This usually consisted of 100 cc. of 50% alcohol, except in the cases where excess amine was used as binding agent, when the solvent was benzene. The mixture was heated under a reflux condenser for six to nine hours. It was then allowed to cool to room temperature and was poured into water. The organic layer was separated, the aqueous layer was made *strongly* basic with sodium hydroxide and extracted several times with ether. The combined ether extracts and the main organic layer were dried over anhydrous magnesium sulfate and then distilled through a Vigreux column or a modified Claisen flask, according to circumstances.

Reactions carried out at higher pressures.—One-fourth of a mole of the chlorohydrine, one-fourth of a mole of the amine, and a slight excess of the alkaline binding agent were dissolved or suspended in 150 cc. of dry benzene, and the mixture was heated in a small autoclave at 125-130°C. for eight to ten hours. The cooled mixture was filtered and the benzene solution was distilled.

Discussion of Results

For the first phase of the study, the reaction of isobutylene chlorohydrine with the weakly basic ethylaniline was chosen. As can be seen from the data in Table I, no amino alcohol was obtained when excess amine was used as the binding agent. Pyridine and sodium acetate also proved to be too weakly basic to bring about a reaction.

TABLE I.—Reaction of Isobutylene Chlorohydrine and Ethylaniline at Atmospheric Pressure

Binding Agent	Solvent	Yield of Amino Alcohol
Excess amine.....	Benzene	0%
Pyridine.....	Benzene	0%
Pyridine.....	Aqueous alcohol	0%
Sodium bicarbonate.....	Aqueous alcohol	48%
Sodium acetate.....	Aqueous alcohol	0%
Boric oxide.....	Aqueous alcohol	11%
Magnesium oxide.....	Aqueous alcohol	28%
Calcium oxide.....	Aqueous alcohol	36%
Potassium hydroxide.....	Aqueous alcohol	26%
Trisodium phosphate.....	Aqueous alcohol	15%

Of the other binding agents tried, sodium bicarbonate was the most satisfactory, and the oxides of calcium and magnesium next. The relatively low yield of amino alcohol, obtained when potassium hydroxide was used, is probably due to the fact that it is too strong a base and caused partial decomposition of the tertiary chlorohydrine to the volatile isobutylene oxide, which escaped from the reaction mixture. From

the above data, it is permissible to conclude that, for a binding agent to be satisfactory, it must be a fairly strong base but that too strong a base causes side reactions which lower the yield of amino alcohol.

The use of sodium bicarbonate and sodium carbonate in the preparation of other amino alcohols from isobutylene chlorohydrine was investigated next. A good yield (47%) of amino alcohol was obtained from methylaniline, using sodium bicarbonate as binding agent and aqueous alcohol as solvent. Dibutylamine gave a 61% yield of the corresponding amino alcohol, and diethylamine a 46% yield. In extending the study to the higher, less basic aromatic amines, it was found that no amino alcohol could be obtained from isobutylene chlorohydrine and diphenylamine or alpha-naphthylamine, either in the presence or the absence of sodium carbonate. This is not especially strange since these amines are so weakly basic that they will not dissolve in dilute hydrochloric acid. For reasons as yet unexplained, dicyclohexylamine yielded no amino alcohol either with or without a binding agent.

Sodium carbonate and sodium bicarbonate proved to be satisfactory binding agents in the preparation of amino alcohols from trimethylene chlorohydrine and diethyl and dibutylamines. In this case also, dicyclohexylamine yielded no amino alcohol. These data are summarized in Table II.

TABLE II.—Preparation of Amino Alcohols from Chlorohydrines at Atmospheric Pressure

Chlorohydrine	Amine	Binding Agent	Yield of Amino Alcohol
Isobutylene.....	Ethylaniline	NaHCO ₃	48%
Isobutylene.....	Methylaniline	NaHCO ₃	47%
Isobutylene.....	Di-n-butylamine	Na ₂ CO ₃	61%
Isobutylene.....	Diethylamine	NaHCO ₃	46%
Trimethylene.....	Di-n-butylamine	Excess amine	33%
Trimethylene.....	Di-n-butylamine	NaHCO ₃	48%
Trimethylene.....	Di-n-butylamine	Na ₂ CO ₃	47%
Trimethylene.....	Diethylamine	NaHCO ₃	53%

Since, with the lower-boiling amines, it is desirable to carry the reaction out in a sealed vessel to avoid losses and since, obviously, sodium carbonate or bicarbonate cannot be used under such conditions, it seemed advisable to investigate the use of other binding agents for this purpose. From the data in Table I, it seemed that magnesium oxide would be suitable. This proved to be the case for the reaction of diethylamine with isobutylene chlorohydrine. Using excess amine as binding agent, a 19% yield of amino alcohol was obtained. Under the same conditions of time, temperature, solvent, and pressure but substituting magnesium oxide for the excess amine, the yield of the amino alcohol was increased to 30%.

The physical constants of the amino alcohols prepared in the course of this work are recorded in Table III. Not all of these have been described before.

TABLE III.—Physical Constants of Amino Alcohols

Amino Alcohol	B.pt. °C.	Press. mm.	n_D^{20}	d_4^{20}
Methylanilino-tert-butyl alcohol.....	132-133°	12	1.5479	1.0160
Ethylanilino-tert-butyl alcohol.....	137-138°	12	1.5418	1.0029
Dibutylamino-tert-butyl alcohol.....	118-119°	21	1.4379	0.8422
Diethylamino-tert-butyl alcohol.....	78-80°	45	1.4253	0.8382
3-Diethylamino-1-propanol.....	85-86°	20	1.4439	0.8600
3-Dibutylamino-1-propanol.....	121-122°	11	1.4476	0.8617

Summary

1. The use of alkaline, inorganic binding agents in the preparation of amino alcohols from chlorohydrines and secondary amines has been investigated.

2. Sodium carbonate and sodium bicarbonate have been shown to be the most satisfactory binding agents for reactions at atmospheric pressure. In many cases, the use of these substances increases the yield of amino alcohol markedly. Magnesium oxide appears to be a satisfactory binding agent for use at higher pressures.

Enzymatic Action in the Presence of Some Common Antiseptics

O. E. RUMPLE and R. J. HARTMAN, Indiana University

Many diversified studies of the influence of foreign materials on enzymatic action have been made. An attempt to compare the antiseptic properties of various compounds by yeast fermentation seems to have been made first by Dreser¹ in a study of colloidal silver preparations.

The effect of mercury compounds on yeast fermentation was studied in somewhat the same manner by Peterson². As a result of his investigation, he was able to classify the mercurials, using mercuric chloride as a standard, into four groups depending upon their ability to inhibit the fermentative process. He concluded that the inhibitive effect of the yeast sugar fermentation, in most cases, is due to the mercuric ion concentration although, in some cases, other components of the solution were concerned.

By means of a simple device for quantitatively collecting the carbon dioxide produced by yeast fermentation, Branham³ confirmed the principles of the yeast fermentation method of comparing antiseptics and also showed that the method had a general application.

The purpose of this investigation was three-fold: first, to study the influence of many common antiseptics on yeast sugar fermentation; second, to compare the effect of certain antiseptics on the enzymatic action of zymase with that of catalase, trypsin, and pepsin; and, third, to determine the influence of these antiseptics on the action of the above enzymes in the presence of normal horse serum.

Experimental

In Table I are listed the antiseptics used in this investigation, showing their trade or common name, their chemical name, and the manufacturer or distributor from whom the antiseptics were obtained. The enzymes studied were yeast zymase, yeast catalase, pepsin, and trypsin.

The acriflavine, merthiolate, metaphen, pepsin, pancreatin, trypsin maltase, and the normal horse serum were supplied through the courtesy of Eli Lilly and Company, Indianapolis, Indiana.

The general method of procedure was to determine the concentration or quantity of antiseptic required to completely impede the activity of each of the enzymes studied.

Yeast Zymase

Ordinary cakes of Fleischmann's yeast were used in this work, and they were purchased every other day to assure fresh starting material. A 20% solution by weight of yeast was used throughout the study. This

¹Dreser, 1917. *Ztschr. f. Exper. Path. U. Therap.* 19:285.

²Peterson, 1926. *Journ. Amer. Med. Assoc.* 87:223.

³Branham, 1929. *Journ. Infect. Dis.* 44:142.

TABLE I.—Antiseptics Used in This Investigation

Trade or Common Name	Chemical Name	Manufacturer or Distributor (U.S.A.)
Alcohol	Ethyl Alcohol	Commercial Solvents Corp.
Acridavine	3,6 Diamino -10- Methylacridinium Chloride Monohydrochloride	Abbott Laboratories
Argyrol		A. C. Barnes Co.
Boric Acid	Boric Acid	Coleman and Bell
Blue Vitriol	Copper Sulfate	Coleman and Bell
Carbolic Acid	Phenol	Mallinckrodt Chemical Co.
Corrosive Sublimate	Mercuric Chloride	Coleman and Bell
Ferric Chloride	Ferric Chloride	Coleman and Bell
Glycotanphene		Tannin Products, Inc.
Lavoris		The Lavoris Co.
Listerine		
Mercurochrome	Dibrom-Oxymercuri- Fluorescein	Hynson, Westcott and Dun- ning, Inc.
Merthiolate	Sodium Ethyl Mercurithiosalicylate	Eli Lilly and Co.
Metaphen	4-Nitro-Anhydro Mercuri Ortho-Cresol	Abbott Laboratories
Neo-Silvol		Parke Davis and Co.
Pepsodent		The Pepsodent Co.
Potassium Permanganate	Potassium Permanganate	Coleman and Bell
Silver Nitrate	Silver Nitrate	Daigger Chemical Co.
S.T. 37	Hexylresorcinol	Sharp and Dohme
Zinc Sulfate	Zinc Sulfate	Coleman and Bell

solution was prepared by dissolving or suspending 40 gm. of the yeast in enough distilled water to make the final volume 200 ml. This yeast suspension was stored in a refrigerator at a temperature of approximately 5° C.

All weighing, accurate to the fourth decimal place, was done on an analytical balance, and all dilutions were made with a burette or pipette or both. All stock solutions were made by dissolving the antiseptic or enzyme in enough distilled water to give the desired concentration. For example, to make a so-called 1-100 solution, one gram of the antiseptic or enzyme was dissolved and diluted with enough distilled water to make the final volume of the solution 1,000 ml.

The test solutions were made up and mixed in the following order: 2 ml. of the desired antiseptic solution, 2 ml. of a 50% sugar solution, 6 ml. of distilled water or serum, 2 ml. of a 20% yeast suspension.

When those antiseptics which did not greatly retard enzymatic action were used, the ratio of the volume of water or serum to the volume of the antiseptic solution varied somewhat, but the total volume of antiseptic solution and water or serum was always maintained at 8 ml. The amount of sucrose solution and yeast suspension was never changed. The above portions were measured from freshly prepared solutions into test tubes by means of a 2 ml. pipette, thoroughly mixed, poured into saccharometer or fermentation tubes and incubated for two hours at a temperature of 38° C., plus or minus one degree.

TABLE II.—A Summary of the Data Obtained in the Study of Yeast Zymase

Antiseptic	End Point in Aqueous Sol. (Concentration)	End Point in a 50% Serum (Concentration)
Alcohol	15.8% (1-6.3)	17.4% (1-5.7)
Acriflavine	1-1200	1-400
Argyrol	1-15	No inhibition
Boric Acid	No inhibition	No inhibition
Copper Sulfate	No inhibition	1-180
Carbolic Acid	1-180	1-150
Corrosive Sublimate	1-18,000	1-6000
Ferric Chloride	No inhibition	No inhibition
Glycotaphen	1-1.7	1-1.5
Lavris	No inhibition	No inhibition
Listerine	1-3	1-2.4
Mercurochrome	1-90	1-50
Merthiolate	1-240	
Metaphen	1-6000	1-4000
Neo-Silvol	No inhibition	No inhibition
Pepsodent	1-5	1-3
Potassium Permanganate	No inhibition	No inhibition
Silver Nitrate	1-18,000	1-120
S.T. 37	1-3500	1-2400
Zinc Sulfate	No inhibition	1-20

Discussion of data obtained with yeast zymase.—In performing the experiments using alcohol as antiseptic, it was found that, when the final concentration of the alcohol was greater than about 16%, a protein precipitate formed as the serum was added to the alcohol mixture and the quantity of precipitate increased with increasing alcohol concentration. No precipitate was observed in those tubes containing only water.

In both aqueous and serum media, it was found that low concentrations of argyrol enhanced the activity of zymase. In a serum medium, some repression was noticed when the concentration of argyrol was increased to about 1-10. No precipitation was observed in either medium within the limits studied.

A discoloration due to a precipitate occurred in the mixture containing the stronger concentrations of acriflavine and metaphen when the yeast and serum were added. The fact that the yeast gave a decidedly heavier precipitate might be due to the acid characteristics of the yeast.

In aqueous solution, boric acid repressed the yeast sugar fermentation but did not completely inhibit it. Apparently the retardation was proportional to the amount of acid added. In serum medium, however, the reaction started in the fermentation tubes containing boric acid before it did in those tubes containing the acid and those not containing it. In the more dilute solution, 1-100, the boric acid apparently increased the activity; in the tubes containing higher boric acid content, retardation occurred although the reaction was not completely stopped.

It is of interest to note that minimum activity of yeast zymase appeared near a copper sulfate concentration of 1-2,000 although complete inhibition was not obtained. The amount of carbon dioxide evolved in-

creased gradually on both sides of this interval. When the serum was added, precipitation occurred near a concentration of 1-900 and continued through a maximum at a concentration of between 1-60 and 1-200. During the first few minutes the activity was greatest at a concentration of about 1-1,000.

The serum was precipitated by the carbolic acid when its final concentration was made more than 1% with respect to phenol. In all dilutions greater than the end point of the experiment (1-80 for aqueous solution and 1-150 for serum solution), the tubes containing serum reacted first and more rapidly than those which did not contain phenol.

Within the range of concentrations studied, mercuric chloride did not precipitate the proteins of the serum.

Ferric chloride did not completely stop yeast sugar fermentation although for concentrations greater than 1-15 in both aqueous and serum media very little carbon dioxide was given off. In aqueous solutions maximum activity occurred at a final concentration of approximately 1-100. The serum formed a jelly-like mass with the iron which was difficult to remove from the fermentation tubes when the final concentration exceeded 1-50.

There was a slight precipitation when the serum was added to the glycotanaphene at a final concentration of 1-2.5. The precipitation increased as the concentration of the antiseptic increased.

Pepsodent and listerine slightly precipitated the serum in concentration from 1-2 or 1-3, but there was no noticeable increase in the precipitation as the concentration of the antiseptics increased.

A curdy, flocculent precipitate formed in all of the fermentation tubes containing mercurochrome with a separation of the precipitate from the more dilute solutions. At a concentration of 1-40 a jelly-like mass was formed. When the serum was added, the precipitation seemed to be more pronounced between the concentrations of 1-60 and 1-120. No precipitation was noted from a solution of a concentration of 1-40.

Neo-Silvol did not inhibit yeast sugar fermentation. All tubes containing the antiseptic, within the concentrations studied, were more active than those which did not contain it.

Experiments using potassium permanganate as antiseptic, with concentrations varying from 1-100 to 1-9,000 in rather small intervals of dilution, were repeated several times. The datum cited in Table II is representative of the whole. Several of the various sets of data showed that the end point in aqueous solution is near 1-1,800; other sets seemed to be more active, the greater the concentration of salt. After 30 minutes, there was approximately two times as much carbon dioxide in the fermentation tube containing a concentration of 1-500 than there was in those tubes containing no antiseptic. There was more or less precipitation of manganese dioxide, increasing with the concentration in all dilutions. When serum was added to the potassium permanganate, precipitation occurred. The extent of precipitation increased with the antiseptic concentration in all tubes having a concentration of salt greater than 1-600. Several trials were made using solutions having a final strength varying from 1-100 to 1-500, and it was found that the tubes containing the salt were more active than those which did not con-

tain it. After 45 minutes, the tube containing a concentration of 1-600 had approximately twice as much gas in it as those containing no potassium permanganate, and the activity seemed to increase with increasing salt concentration.

Silver nitrate began precipitating the proteins of the serum in a concentration of 1-15,000 with respect to the salt, and the amount of precipitation increased as the concentration of silver nitrate increased. The degree of inhibition was also proportional to the amount of salt present.

Zinc sulfate was studied from a concentration of 1-4 to 1-15,000 inclusive. As the concentration of salt increased, the activity also increased. Within the range of the concentrations studied, the tubes containing zinc were more active than those which did not contain zinc. When the serum was added, precipitation started at a concentration of about 1-1,000 and increased as the zinc increased through a maximum near a concentration of 1-150 with no immediate precipitate from a solution of 1-15 with respect to zinc sulfate.

From the summary of the data obtained in the study of yeast zymase, Table II indicates, with the exception of zinc sulfate and copper sulfate, that more antiseptic is necessary to produce complete inhibition in a 50% solution of normal horse serum than is required to produce complete inhibition in an aqueous solution. Whether the serum increases the activity of the yeast zymase or decreases the activity of the antiseptic or both is problematical. Those antiseptics for which no end point was reached generally showed a greater activity in serum when the same concentrations were used in both aqueous and serum media.

Catalase

The general method of procedure was to determine the concentration or quantity of antiseptic required to completely inhibit the liberation of molecular oxygen from hydrogen peroxide by yeast catalase.

The yeast used was the ordinary small cakes made by the Fleischmann Yeast Company and secured every other day to assure fresh working suspensions. Two per cent solutions by weight were used throughout the study of catalase. It was made by suspending 4 gm. of yeast in enough distilled water to make the final volume 200 ml. This suspension was stored in a refrigerator at a temperature of approximately 5° C.

The following method of procedure was followed throughout the study of catalase. The desired amount of antiseptic was introduced into a test tube together with 2 ml. of a 2% yeast suspension and enough distilled water or serum added to make the final volume 10 ml. The tube content was then thoroughly agitated. After this mixture had been incubated for two hours at room temperature (about 23° C.), 2 ml. of 0.3N hydrogen peroxide was added. After mixing, the contents of each test tube were poured into a fermentation tube and incubated at room temperature for another hour. The smallest amount of antiseptic required to prevent the liberation of oxygen from the hydrogen peroxide was considered the end point of the experiment.

The antiseptic solutions used in the study of catalase were prepared in the same way as those used in the study of yeast zymase.

The hydrogen peroxide used was commercial peroxide manufactured by Coleman and Bell. A 0.3N solution was employed to determine whether or not the catalase had been destroyed. It was prepared by first standardizing a potassium permanganate solution and then titrating this solution against the unknown hydrogen peroxide solution. After determining the normality of the peroxide, the proper dilution was made by means of a burette.

The test solutions were made up and mixed in the following order: 2 ml. of the desired antiseptic solution, 2 ml. of a 2% yeast suspension, 6 ml. of distilled water or serum.

When those antiseptics which did not greatly retard enzymatic action were used, the ratio of the volume of water or serum to the volume of the antiseptic solution varied somewhat, but the total volume of antiseptic and water or serum was always maintained at 8 ml. The concentration and volume of yeast suspension never changed.

Discussion of data obtained with catalase.—Acriflavine was studied within concentration intervals of from 1-50 to 1-1,500 inclusive. In Table III is recorded a summary of the data obtained in this study of yeast catalase. In aqueous solution, all of the concentrations evolved more oxygen than samples which did not contain any antiseptic. Qualitatively, the greater the concentration of acriflavine, the greater was the evolution of oxygen. In the more concentrated solutions, however, the amount of gas given off seemed to become more constant. When serum was added, precipitation occurred in all tubes containing acriflavine. Concentrations contained about the same amount of oxygen as the tubes containing no antiseptic.

TABLE III.—A Summary of the Data Obtained in the Study of Yeast Catalase

Antiseptic	End Point in Aqueous Sol.	End Point in Serum Sol.
Acriflavine	No inhibition	No inhibition
Alcohol	No inhibition	No inhibition
Argyrol	No inhibition	No inhibition
Carbolic Acid	1-50	1-50
Mercuric Chloride	1-1000	1-150
Metaphen	No inhibition	No inhibition
Neo-Silvol	No inhibition	No inhibition
Silver Nitrate	1-6250	1-70
S.T. 37	1-1250	No inhibition

In all concentrations studied below 60%, alcohol catalyzed the liberation of oxygen from hydrogen peroxide. Maximum activity appeared to be between 20% and 40% alcohol with a gradual decrease on both sides of this interval. When the serum was added, precipitation started near a concentration of 40% and increased as the amount of alcohol increased. Alcohol accelerated the reaction between the concentrations of 5% and 60% with maximum activity near 25% alcohol. Concentrations above 60% were less active than those tubes containing no alcohol.

All tubes containing argyrol were very active, denoting that the

colloidal silver which it contains promoted the liberation of oxygen from hydrogen peroxide. The reaction proceeded so rapidly, in aqueous solution, that it was practically complete before the solution could be transferred from the test tubes to the fermentation tubes. However, the argyrol was less active in serum medium than it was in aqueous solution. As the concentration of serum decreased and the concentration of argyrol increased, the activity increased accordingly. In a concentration of 10% argyrol and 40% serum, the reaction occurred almost instantaneously.

In aqueous solution, phenol acted catalytically between the concentrations of 1-75 and 1-1,000, the limits of this study. Maximum activity seemed to occur near a final concentration of 1-150. In serum medium, precipitation started at a concentration of approximately 1-75 and increased as the amount of phenol increased.

Mercuric chloride was studied in rather small intervals of concentration between dilutions of from 1-125 to 1-10,000. It was found, in aqueous solutions, that the salt increased the rate at which oxygen was liberated in solutions having concentrations between 1-4,500 and 1-10,000. In solutions stronger than 1-4,500, inhibition gradually increased with increasing concentration. The reaction was completely stopped near a concentration of 1-1,000. In serum medium, precipitation occurred with a bichloride concentration of about 1-750 and increased as the amount of salt was increased. Again the antiseptic increased the activity between the concentration 1-500 and 1-10,000.

In all concentrations of metaphen studied, from 1-625 to 1-10,000, inhibition was not observed. In aqueous solution, all concentrations within this interval liberated more oxygen than those tubes containing no metaphen. It appeared that there was a small increase in the amount of oxygen near a final concentration of 1-2,000. In serum medium, all tubes containing metaphen as well as those tubes not containing metaphen evolved about the same amount of oxygen.

In aqueous medium, the volume of oxygen increased as the concentration of neo-silvol increased between the concentrations 1-7 and 1-300. In a serum medium, the volume of oxygen remained fairly constant throughout this interval.

Silver nitrate, in aqueous solution, did not accelerate the reaction within the limits of the concentrations studied. Beginning with the most dilute concentration of the salt, 1-30,000, the volume of the oxygen liberated became less as the concentration of silver nitrate increased. In a serum medium, precipitation occurred near a concentration of 1-1,600 and increased as the amount of silver increased. In a serum medium, precipitation occurred near a concentration of 1-1,600 and increased as the amount of silver increased. All tubes containing serum with a dilution of antiseptic greater than 1-50 liberated about the same volume of oxygen after one hour as those tubes having no antiseptic. Those tubes containing silver nitrate seemed to react more rapidly at the beginning.

The activity of all concentrations of hexylresorcinol between 1-2,000 and 1-20,000 seemed to be fairly constant although in aqueous solution there did seem to be a slight increase in the volume of oxygen near a concentration of 1-2,500.

A review of the data obtained in the study of catalase, Table III, indicates, with the exception of carbolic acid, that more antiseptic is necessary to produce complete inhibition in an approximately 60% solution of normal horse serum than is required to produce complete inhibition in an aqueous solution. The same was observed in the study of yeast zymase, Table II.

Pepsin

The pepsin used in this study was of the soluble type and furnished through the courtesy of Eli Lilly and Company, Indianapolis, Indiana. The solutions were prepared daily and stored in a refrigerator at a temperature of approximately 5° C. A 2% solution was used throughout which was made by dissolving 4 gm. of pepsin in sufficient distilled water to make the final volume 200 ml.

The other solutions used with pepsin were prepared in a manner similar to that employed in the study of yeast zymase and catalase.

Briefly, the general method of procedure consisted in determining the smallest amount of antiseptic that would prevent the digestion of "red" blood fibrin during a period of three hours.

The actual test solutions were prepared by mixing 2 ml. of the desired concentration of antiseptic, 4 ml. of distilled water, 2 ml. of buffer mixture, 2 ml. of a 2% solution of pepsin, and finally a few small pieces of "red" blood fibrin. The mixtures were then incubated for three hours at 38° C. The above portions were measured from freshly prepared solutions into test tubes by means of a pipette.

The buffer mixture was prepared according to the tables of Clark and Lubs by mixing 20.75 ml. of 0.2 N hydrochloric acid and 25 ml. of 0.2 N potassium chloride with enough distilled water to make 100 ml. This solution has a pH of 1.4.

The blood fibrin was dyed in a 2% aqueous solution of amaranth red for 30 minutes. All excess dye was then thoroughly removed by washing with water whose acidity had been previously adjusted to a pH of 3.0 with hydrochloric acid. This gave a red fibrin whose red color would not come out in acid media. Even the slightest digestion of the fibrin was made apparent by a noticeable red color in the test tubes. The dye and blood fibrin were obtained from Coleman and Bell, Norwood, Ohio.

When those antiseptics which did not greatly retard enzymatic action were used, the ratio of the volume of water to the volume of the antiseptic varied, but the total volume of the two was always maintained at 6 ml. Mercuric chloride and hexylresorcinol were the only antiseptics studied with pepsin.

A review of the data obtained in the study of pepsin indicated that for mercuric chloride the end point, in aqueous solution, is near a final concentration of 1-250. Hexylresorcinol was found not to inhibit pepsin activity.

Again it appeared that, in certain definite concentrations, mercuric chloride had some accelerating action. Apparently, more digestion of the fibrin took place near a concentration of 1-1,000 than at any other concentrations.

Trypsin

The trypsin used was manufactured by Fairchild Brothers and Foster and was furnished through the courtesy of Eli Lilly and Company. A 2% solution was prepared daily by suspending 4 gm. of trypsin in sufficient distilled water to bring the volume to 200 ml. The suspension was stored in the refrigerator.

Briefly, the general method of procedure consisted in determining the smallest amount of antiseptic that would prevent the digestion of "blue" blood fibrin during a period of three hours.

The actual test solutions were prepared by mixing 2 ml. of the desired concentration of antiseptic, 4 ml. of distilled water, 2 ml. of buffer mixture, 2 ml. of a 2% solution of trypsin, and finally a few small pieces of "blue" blood fibrin. The solutions were then incubated for three hours at 38° C. The above portions were measured from freshly prepared solutions into test tubes by means of a pipette.

The buffer solutions were prepared according to the table of Clark and Lubs by mixing 46.8 ml. of 0.1 N sodium hydroxide and 50 ml. of 0.1 molar monopotassium phosphate with distilled water to make 100 ml. This solution has a pH of 8.

The blood fibrin was dyed in a 2% solution of aniline blue for 30 minutes. All excess dye was then thoroughly removed by washing with water whose basidity had been previously adjusted to a pH of 8 with ammonium hydroxide. This gave a blue fibrin whose blue color would not come out in basic media. Even the slightest digestion of the fibrin was made apparent by a noticeable blue color in the test tubes.

Phenol was the only antiseptic studied in connection with trypsin. A review of the data obtained in the study of trypsin indicates that for phenol the end point, in aqueous solution, is near a final concentration of 1-50.

Summary

A comprehensive and diversified study has been made concerning the influence of antiseptics upon enzymatic action.

The influence of alcohol, acriflavine, argyrol, boric acid, copper sulfate, carbolic acid, corrosive sublimate, ferric chloride, glycotanphene, lavis, listerine, mercurochrome, merthiolate, neo-silvol, pepsodent, potassium permanganate, silver nitrate, hexylresorcinol, and zinc sulfate on yeast sugar fermentation, in aqueous media and in the presence of normal horse serum, has been studied. In all instances, with the exception of zinc sulfate and copper sulfate, it was found that more antiseptic was required to inhibit carbon dioxide formation in the presence of normal horse serum than was required to inhibit carbon dioxide formation in aqueous solution. The order in which the antiseptics prevented yeast sugar fermentation is given in descending order: mercuric chloride, silver nitrate, metaphen, hexylresorcinol, acriflavine, merthiolate, carbolic acid, mercurochrome, etc.

In the study of the influence of acriflavine, alcohol, argyrol, carbolic acid, mercuric chlorine, metaphen, neo-silvol, silver nitrate, and hexylresorcinol on catalase, in aqueous solution and in the presence of normal

horse serum, it was found, also, that, with the exception of carbolic acid, more antiseptic was required to prevent the liberation of molecular oxygen from hydrogen peroxide by the catalase in serum media than was required to prevent the liberation of oxygen from hydrogen peroxide by the catalase in aqueous solution. It was particularly observed that argyrol was much more active in an aqueous medium than in a serum medium.

In the study of the influence of mercuric chloride and hexylresorcinol on pepsin, it was found that much more antiseptic was required to enhance the action of pepsin than was required to inhibit the action of the other enzymes studied. A mercuric chloride concentration of 1-18,000 prevented yeast sugar fermentation; a concentration of 1-1,000 was required to stop the action of yeast catalase. It required a bichloride concentration of about 1-300 to inhibit the action of pepsin.

It was found that a carbolic acid concentration of 1-50 was necessary to prevent the digestive function of trypsin. The same concentration inhibited the liberation of oxygen from hydrogen peroxide; a concentration of 1-180 was required to stop yeast sugar fermentation.

From a survey of the data, it will be noted that, with two or three exceptions, much more antiseptic was required to inhibit the action of the enzymes in a serum medium than was required to prevent the action in an aqueous medium.

As a general rule, the antiseptics studied in this paper had a catalytic or promoting effect within a certain definite range of concentrations, and this effect was different for each enzyme.

A Photographic Determination of the Relative Intensities of Three Chemiluminescences

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In the present experiments, which were carried out in the laboratories of the Cleveland Clinic Foundation, measurements were made of the relative intensities of the luminescences resulting from the oxidation of urine, lophine (2, 4, 5-triphenylimidazole), and luminol (3-aminophthal hydrazide). The solutions used to produce the luminescence have been described in a previous article.¹ The light was maintained by means of the "lumistat," an automatic feeding device which maintains chemiluminescence at almost constant intensity. This device is to be the subject of a forthcoming article sometime in the near future. The lights were photographed on Eastman's Super XX roll film. A camera shutter was in each instance placed between the film and the light source to control the time of exposure. With this shutter interposed, the light source was about one inch from the film.

An exposure of 30 minutes was allowed for urine luminescence, 2 seconds for the lophine, and 0.08 seconds for the luminol. The densities produced on the film are shown in Table I and in Fig. 1. They were

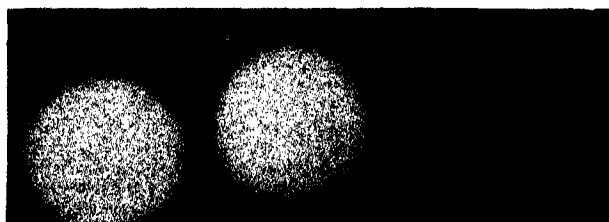


Fig. 1. A. Light from lophine, 2 sec.
B. Light from luminol, 0.08 sec.
C. Light from urine, 30 min.

TABLE I.

Luminescent Material	Density	Log Exposure	Exposure	Time in Seconds	Intensity
Urine.....	0.83	2.43	0.0269	1800	1.49×10^{-5}
Lophine.....	1.87	1.64	0.3468	2	0.173
Luminol.....	2.03	1.74	0.5495	0.08	6.87

¹Cottman, Journ. Chem. Ed. 16:292-4 (1939).

measured on a densitometer of the Hartman type. The logs of the exposures were read from the proper H & D curves², and the exposures were determined. Assuming no reciprocity failure, $E=IT$, and $I=E/T$, in which I is the intensity, E is the exposure, as derived from the H & D curve, and T is the length of the exposure in seconds.

It may be determined from the data in Table I that the intensity of luminol luminescence is about 4.6×10^5 times as great as that of urine and about 40 times as great as that of lophine. Lophine luminescence is about 1.16×10^4 times as intense as that of urine.

Summary

Through the use of photographic methods, determinations were made of the relative intensities of the chemiluminescence produced by the oxidation of luminol, lophine, and urine, respectively. Luminescence from luminol is about 460,000 times as bright as that from urine and about 40 times as bright as that from lophine.

²Supplied by the Eastman Kodak Company.

The Action of the Esters of Chlorosulfonic Acid on Di-*n*-Butylamine

W. W. BINKLEY with ED. F. DEGERING, Purdue University

The reactions between the lower dialkylamines and the lower esters of chlorosulfonic acid at 0°C. were described by Delepine and Demars¹ in 1923. Similar reactions between the lower esters of chlorosulfonic acid and di-*n*-butylamine were conducted by Binkley and Degering in 1939.² The present study was an investigation of the reactions between the lower esters of chlorosulfonic acid and di-*n*-butylamine at the of these experiments are as follows:

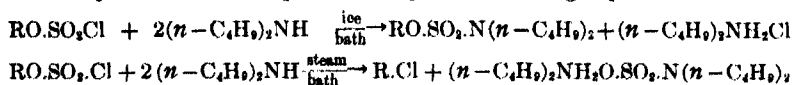
A three-neck-distilling flask was equipped with a mercury-seal mechanical stirrer and a small dropping funnel. The third neck was attached to a gas analysis train containing four traps. The two traps nearest the reaction flask were surrounded by cold water baths while the other two traps were placed in dry ice-acetone baths. The apparatus was constructed in such a manner that a current of dry air could sweep any gases from the reaction flask into the gas analysis train. After one-fifth of a mole of di-*n*-butylamine was placed in the reaction flask, the agitation was begun. The flask was heated with a steam bath during the careful addition of one-tenth of a mole of the alkyl chlorosulfonate from the dropping funnel to the di-*n*-butylamine. The reaction mixture was heated for 30 minutes after the addition of the alkyl chlorosulfonate, while a slow current of dry air was allowed to pass through the apparatus. The cold water baths removed from the two traps nearest the reaction flask, these traps were warmed with steam to distill any volatile substances into the remaining two traps for analysis. The results of these experiments are as follows:

Alkyl chlorosulfonate	Percentage of alkyl chloride formed (based on the alkyl chlorosulfonate used)
methyl	60
ethyl	53
<i>n</i> -propyl	46

The oily residue in the reaction flask was largely di-*n*-butylammonium-*N,N*-di-*n*-butylamidodisulfonate in all of these experiments. This compound was readily converted to di-*n*-butylamine hydrochloride and *N,N*-di-*n*-butylamidodisulfonic acid (m.p. 132-3°C.) with hydrochloric acid.

Conclusions

The reactions between lower esters of chlorosulfonic acid and di-*n*-butylamine at the temperatures of an ice bath and steam bath are markedly different as represented by the following equations:



¹Delepine, M., and R. Demars, 1923, *Bull. Sci. Pharmacol.* 30:577-9.

²A portion of a thesis submitted to the faculty of Purdue University in partial fulfillment of the requirements of the degree of Doctor of Philosophy, June, 1939.

GEOLOGY AND GEOGRAPHY

Chairman: T. M. BUSHNELL, Purdue University

The program of this section was well attended, those present including a number of students of the State Teachers College. The two papers by Fred J. Breeze, listed by title below, were omitted because of the author's illness. The program was short, and the less hurried presentation of the papers permitted more discussion than usual.

W. D. Thornbury, Indiana University, was elected chairman of the section for 1940.

ABSTRACTS

The influence of the weather on crop yields in Indiana studied by the climograph technique. STEPHEN S. VISHER, Indiana University.—This is a study of the correlation between the yields of the various crops and such weather conditions as monthly average temperatures and rainfall totals, depth of snowfall, length of growing season, and number of days with temperature above 90°, over the period from 1887 to 1939, inclusive. The climographs show that monthly totals of rainfall and average temperatures affect crop yields to an extent which is surprising in view of the fact that the harvest depends upon several factors, including the weather of at least the entire period of growth. The departures from the monthly normals are, nevertheless, followed by rather consistent variations in yield. For wheat, Februaries which are drier than normal are advantageous, as are warmer Marches, cooler Mays, and winters with about 25 inches of snowfall. For oats, relatively cool Mays and wet, cool Junes and Julys are beneficial. For hay, relatively warm springs, wet Mays, and cool, wet Junes are advantageous. For corn, warm Mays and Junes and relatively cooler Julys and Augusts are desirable; more rainfall than Indiana's average amount is helpful to corn, especially in July and August.

The part of this paper concerned with corn appeared in *Indiana Farmers Guide* 95(1939):566. An extended discussion of these topics will appear as two chapters in a forthcoming volume, *The Climate of Indiana*.

A plan for measuring the recession of Liston Creek Falls. FRED J. BREEZE, Fort Wayne Extension Center, Indiana University.—Published by title.

1939, A centennial year in geology. FRED J. BREEZE, Fort Wayne Extension Center, Indiana University.—Published by title.

The True Value of the Earth's Rotation as a Deflective Factor

A. V. LOTT, Sellersburg

Introduction

The deflective effect of the earth's rotation has been known and generally understood since the days of Ferrel. The laws of deflection have been established, and scientists generally believe that all air currents must obey those laws. Unfortunately, however, the acceptance of the earth's rotation as a deflective factor seems to have resulted in a general failure to give due consideration to any other deflective factors which may be present. Consequently, certain atmospheric movements have been attributed to the deflective effect of rotation when, in reality, they may have been due to factors, concerning which little definite information is available to students and average readers. This suggests the urgent need for a further study and a better understanding of all the factors which seem to work together to produce a deflection of air currents.

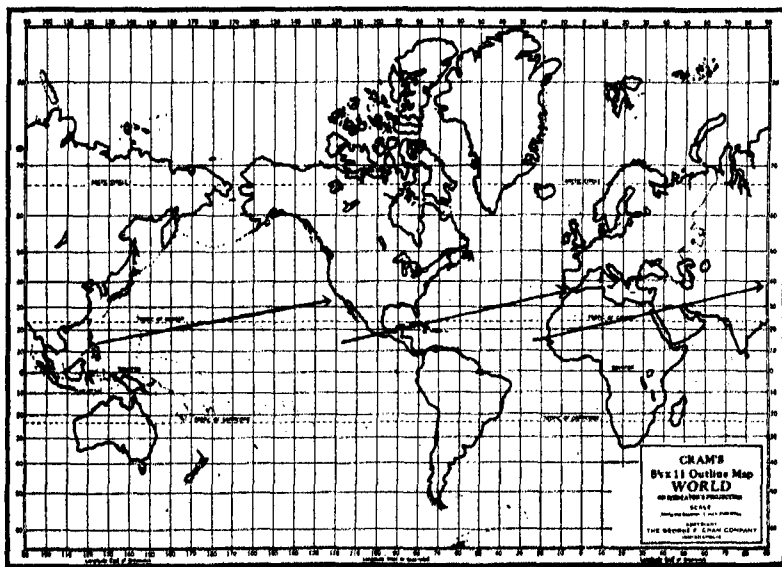


Fig. 1. Approximate positions and direction taken during years of sunspot minima of the three equatorial outflows moving into the northern hemisphere above the level of the surface winds.

Some evidence seems to indicate that the earth's rotation, when it acts alone, does not affect air currents in just the way that is now generally believed. Since the deflection seems to occur only when other

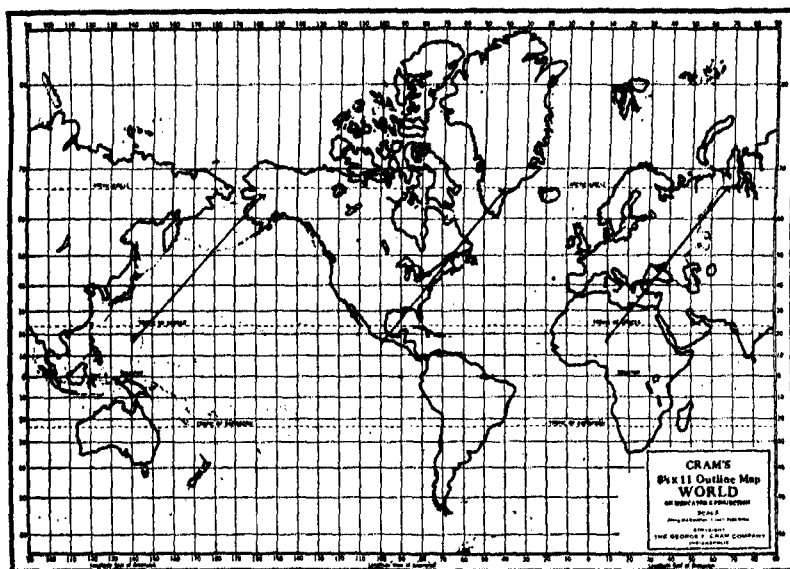


Fig. 2. Approximate positions and the direction taken during years of high sun-spot maxima of the three equatorial outflows moving into the northern hemisphere.

factors are present, it is suggested that the observed deflection may be due, at least partly, to other factors. If further studies by other investigators should indicate that this possibility is really a fact, it would shed new light upon many problems that are now not fully understood.

Variations in the other factors which may affect deflection should cause or permit variations in deflection even when there is no appreciable change in the earth's period of axial rotation. It is the purpose of this paper to call attention to certain atmospheric movements which are said to be due to the deflective effect of rotation, to show why the accepted explanation is not altogether satisfactory, to direct attention to certain factors which seem to aid in causing deflection, to suggest a new interpretation of the observed phenomena, and to show how the new interpretation may lead to a better understanding of some problems that are not yet fully understood.

Some Theoretical Effects of Rotation

When the deflective effect of the earth's rotation became generally understood and the theory became popular, all freely moving bodies were supposed to be affected. All air currents had to be affected. Some believed that the courses of ocean currents were affected. Others asserted that the water in the rivers bore more heavily upon the right bank than upon the left. The rotatory circulations around cyclones and anti-cyclones were attributed to the effect of the earth's rotation. When the southeast trade winds crossed the equator they were said to be deflected toward the right, and the major movements of the general

atmospheric circulation, the easterly winds of low latitudes and the westerly winds of higher latitudes, were considered to be due to this defective effect upon air currents moving between the equator and the poles.

These beliefs have been modified to some extent. Some scientists now readily admit that only air currents are appreciably affected, and probably not all of these. However, the great majority seem to believe that the effect of the earth's rotation is very real and that all air-flows must obey the laws of deflection.

Objections to the Accepted Theory

Scientists once believed that every air-flow that occurred was, in one way or another, the result of some convectional movement. The convectional theory of cyclonic formation was widely accepted. Briefly, the theory required an updraft of air with a horizontal current flowing at the top to carry away the rising air currents. Air was supposed to flow in from the surrounding areas toward the center of greatest activity, the inflowing currents being deflected toward the right in one hemisphere and toward the left in the other, producing the familiar rotatory movement of the cyclonic circulation.

This theory seemed to be fairly satisfactory for a time, especially in accounting for the formation of extra-tropical cyclones, but it could not give an adequate explanation for the cyclones of tropical origin. Cloudy, unsettled weather with showers, squalls, and irregular winds often prevailed throughout large areas in the hot humid sections of the tropical oceans. Theoretically, the conditions seemed favorable for cyclonic formation; yet the cyclonic circulation did not always develop. Since the earth rotates continually, the defective effect of rotation should be ever-present. The frequent failure of the cyclonic circulation to develop seemed to indicate that rotation was an effective defective factor only when all conditions were right. It also indicated the possible presence of some other factor which could assist the earth's rotation in producing the rotatory movement.

The convectional theory of cyclonic formation was followed by the polar frontal theory, which became increasingly popular following the advent of a new method of weather forecasting known as air mass analysis. The new theory seemed to offer a more satisfactory explanation of cyclonic formation, but difficulties were encountered in explaining the formation of tropical cyclones owing to the slight temperature discontinuity which prevailed in the lower latitudes. Some of these difficulties seem to have been removed by Scofield's suggestion (1) that "the temperature discontinuity must be slight and the wind discontinuity great."

The idea that tropical cyclones were of frontal origin was first established by Bjerknes in 1920, and there seems to be a growing tendency among meteorologists to accept this view. The term "frontal origin" should not be confused with the term "polar frontal origin." The polar front approaches from the northwest and is made up of polar continental or polar marine air. The term "frontal" may include the tropical fronts which mark the boundary between the trade winds of the oceanic

anticyclones and the doldrums or, if the doldrums are absent, the boundary between the northeast trades and the southeast trades. The north tropical front is most clearly defined when the Bermuda-Azores High is very strongly developed. Tropical cyclones form in certain favorable areas and move along this front during the period when the pressure gradient is unusually strong. The unusual pressure gradient may have great significance. It may be the factor which assists the earth's rotation in producing the rotatory movement.

Deppermann (2), when discussing the typhoons that originate in the China Sea, concludes that the typhoon "arises at the junction of two or more of the main air streams, such as the trades, northers and southwest monsoon." According to this conclusion, the cyclonic circulation cannot be due to deflection of air currents directly to the right by the earth's rotation. It seems to be the natural result of converging air currents that move in nearly opposite directions.

Algue (3), after observing the formation of tropical cyclones in western Pacific waters for more than twenty years, concluded that the cyclone formed "neither in a region of low nor in a region of high pressure but in a neutral zone." A study of the pressure charts for the western Pacific and the adjoining areas of eastern Asia shows that the neutral zone was always bounded by one or more anticyclonic fronts. Air currents from these fronts could have been the direct cause of the rotatory movement.

Deppermann (2) makes the further suggestion that the typhoon may possibly arise from a surge of the trade throwing the front farther south than usual, against the opposition of the southwest monsoon. The results of such a surge or sudden extension of a front will be clearly understood after observing the following simple experiment: A deep basin is filled with water, the hand is completely submerged and given, from the wrist outward, a sudden movement toward the right. This movement represents the surge or sudden extension of a front. If the hand is in the proper position relative to the surface of the water, an eddy will form just beyond the fingers and move obliquely toward the right. This eddy always whirls in an anticlockwise direction. It is practically identical with the familiar rotatory circulation that surrounds the cyclonic storms of the northern hemisphere.

When the water has quieted, the experiment is repeated by moving the hand toward the left. A clockwise eddy forms and moves obliquely toward the left. Its whirling motion is practically identical with the circulation that surrounds the cyclonic storms of the southern hemisphere.

This experiment shows clearly that the cyclonic circulation may be the direct result of frontal action. It may be produced without any assistance from the earth's rotation.

These evidences and others found in the literature do not give satisfactory support to the view that the rotatory motion is the result of a direct deflection to the right in one hemisphere and toward the left in the other. If the earth's rotation is a factor in cyclonic formation at all, it must act indirectly and through the formation of anticyclonic fronts which move toward the right in the northern hemisphere and toward the left in the southern hemisphere.

Algue (3), who was once Director of the Philippine Weather Bureau, wrote at length on the normal winds of the Philippine Archipelago. He concluded that the southwest winds which sometimes prevailed in that area were not deflected southeast trades but winds of a cyclonic character. The proximity of this area to the region where the southwest monsoon is most fully developed seems to support his view. The winds in this region are not only affected by the Asiatic land mass but also by the Asiatic thermal depression. The winds at higher levels may also have some effect upon the surface circulation. Theoretically, a terminal anticyclone should lie over Asia during the summer months. The anticyclonic winds which should blow at higher levels, when aided by the geographical conditions that are found in that area, could conceivably produce cyclonic winds at the surface. When all things are considered, it seems unwise to attribute the observed circulation to the deflective effect of rotation until after due consideration has been given to the other possible factors.

Deflection seems to be a factor of major importance in determining world climates. Climatic changes of great magnitude possibly could not occur if rotation were the only or even the major deflective factor. The major winds of the general circulation now blow in a general east-west direction. Consequently, belts of similar temperatures also tend to develop in a general east-west direction, and the warm air of a given latitude tends to remain near that latitude. Some of the equatorial heat escapes upward and outward through the antitrades but this heat is carried eastward by the westerly winds. Some heat from the same region also escapes through the warm ocean currents, but they also are deflected eastward under the influence of the westerly winds. These conditions tend to produce a world climate that is marked by climatic zones. The formation of climatic zones seems thus to be partly due to the fact that the warm air and ocean currents from lower latitudes are deflected eastward before they reach the polar regions. If these currents were not deflected eastward, a period of relative climatic uniformity might prevail because the higher temperatures from lower latitudes would then be carried directly to higher latitudes. It seems, therefore, that deflection is a very important climatic factor. If the deflection is due mainly to the earth's rotation, world climates must have been marked by climatic zones throughout all the ages of earth history. Some modification of the zonal climate could have occurred as a result of changes in geographical conditions. Further modification could have occurred as a result of variations in the earth's period of axial rotation. Yet the climatic zones must have persisted from age to age. It seems that this would cause the normal climate of the polar regions to be either cool or cold. Warm climates in those regions would occur only under unusual geographical conditions. Yet mild climates have prevailed in polar regions throughout long periods and under geographical conditions that were apparently not especially favorable for the movement of warm ocean currents into such high latitudes.

Scientists generally recognize the difficulty of making an adequate explanation for the occurrence of such mild climates in the higher latitudes. Some feel that the problem is inexplicable. Many do not realize

that much of the difficulty lies not in the problem itself but in the theory of circulation that is now generally accepted. More recent studies (4) of the general circulation indicate that it is a very complex phenomenon, but many scientists still cling to the earlier conclusions which held that the warm currents which move from the equator toward the poles must be deflected toward the right in one hemisphere and toward the left in the other as a result of the earth's rotation. Therefore, these warm currents can never reach the polar regions. If the old theory is correct, climatic changes of great magnitude are difficult to explain. The changes must necessarily be generally slight.

Scientists who have studied the matter have accumulated such a mass of evidence which points to climatic changes of great magnitude that such changes can no longer be doubted. The fact that the marked changes have occurred seems to support the view that deflection has not always been as great as it is today. In other words, rotation cannot be the only or even the major factor affecting deflection.

Several investigators have, without questioning the value of the earth's rotation as a deflective factor, attempted to show how the major climatic changes could have occurred. Their explanations include changes in the earth's orbital elements, continental drift, reversal of the deep sea circulation, changes in the oblateness of the earth, emission of solar electrons, changes in geographical conditions or land elevation, and other theories and hypotheses. This wide diversity of opinion among geologists and climatologists may be due to the fact that too much importance has been ascribed to the earth's rotation as a deflective factor.

Further evidence which seems to question the value of rotation as a deflective factor is found in the fact that the most important airflows in the world do not fully obey the established laws of deflection. Deflection is supposed to vary directly with the latitude and inversely with the velocity of the moving current. Evidence hitherto largely ignored suggests that it varies directly with the velocity of the general circulation rather than inversely with the velocity of the moving current.

The general circulation of the atmosphere is usually attributed primarily to the temperature inequality between the equator and the poles, the cold, heavy air from the higher latitudes presumably flowing toward the equator, while the warm lighter air rises in the equatorial region. Scientists once believed that the warm, lighter air rose to the top of the atmosphere and moved away into the higher latitudes as an overflow, but further studies revealed the astonishing fact that the warm air did not rise to the top of the atmosphere. Temperature recordings made by balloons sent aloft in different areas showed that the lowest recorded temperatures at high altitudes were found in the equatorial region, while somewhat higher temperatures were recorded at the same altitudes in the polar regions. This suggested that air currents in the stratosphere were descending in the equatorial region and rising at the poles. The circulation in the stratosphere has been described as a "mirror image" of the circulation that exists in the

troposphere. In other words, according to present knowledge, the air at the top of the atmosphere moves from the polar regions toward the equator and then descends until it meets the warm air of the equatorial region which rises from below. The two currents then unite and move outward into the higher latitudes through the antitrades. This outflow from the equatorial region is not uniform throughout the earth's circumference, but, rather, it seems to flow in greater volume through three separate streams into the northern hemisphere. These three streams, with other similar streams that flow into the southern hemisphere, may be called the most important air-flows in the world because they are important factors in the formation of world climates. The air which flows outward through these streams moves obliquely downward toward the surface of the earth and forms belts of increased pressure near latitudes 30 degrees north and south of the equator and then continues onward into the higher latitudes as the westerly winds.

When air flows into a region, it causes an increase in the atmospheric pressure within that region unless this is counterbalanced by an outflow. If the inflow is greater than the outflow it should result in increased pressure until the air eventually breaks through at the weakest point and flows outward. A further flow into the region should cause the pressure to build up again, and the process might continue indefinitely.

The three atmospheric streams flowing into the middle and higher latitudes of the northern hemisphere should, theoretically, produce there a higher atmospheric pressure. During this particular age of earth history one of these equatorial outflows seems to terminate in the North Pacific, forming an area of increased pressure that usually lies between the Hawaiian Islands and the western coast of North America. It may be identified as the North Pacific anticyclone. This area of high pressure seems gradually to increase in intensity until a mass of air breaks away and moves eastward with the prevailing winds. The Pacific anticyclone then decreases in intensity, but it gradually builds up again until another mass breaks away and moves eastward as a migratory anticyclone. This process continues indefinitely.

The Pacific anticyclone does not always remain in a fixed position. Its outflowing currents which take the form of migratory anticyclones sometimes move northeastward or northward instead of eastward. The anticyclone does not always extend over its normal oceanic area but may reach eastward, forming the Great Basin anticyclone. When it extends so far eastward, it is usually associated with a greater number of deep lows that move rapidly eastward along the northern border of the United States. When the anticyclone does not extend eastward over the land area, it seems to be associated with a lesser number of lows which are usually of lesser intensity and which do not move so rapidly nor so directly eastward. When the anticyclone feeds northward toward Alaska, it seems to be associated with lows which move rather slowly more nearly from north to south than eastward. These associations seem to indicate that the position of the anticyclone and the direction taken by its outflowing current must be related in some way to the strength or the velocity of the inflowing stream. If the in-

flowing stream is stronger than normal or if it is flowing at a greater than normal velocity, it seems to terminate farther eastward, and the associated conditions suggest a more active general circulation. If the atmospheric stream is weaker than normal or if it is flowing at a sub-normal velocity, it seems to feed northward toward Alaska, and the associated conditions suggest a more sluggish general circulation.

These observations seem to indicate that a strong or active equatorial outflow is deflected eastward more rapidly than a slower outflow. In other words, the deflection of the equatorial outflow varies directly with the velocity of the general circulation.

Deflection is supposed to vary inversely with the velocity of the moving current; that is, the greater the velocity, the less is the deflection from a straight course, and the less the velocity, the greater is the deflection. These theoretical movements are in direct opposition to the movements that have been actually observed. This discrepancy indicates that the entire subject should be given further consideration and suggests that the earth's rotation may not be the only or even the major factor which causes the deflection.

Factors Which Cause Deflection

In none of the cases which have been considered can the observed deflection be attributed positively to the earth's rotation. The rotatory motion of cyclonic storms seems to be the result of frontal action rather than a direct effect of rotation. The deflection of the southeast trades, wherever it occurs, seems to be due, at least partly, to the proximity of anticyclonic winds, large land masses, or thermal depressions, or to some interference in the circulation, due to mountain ranges, islands, etc. The variations in deflection that seem to correspond with variations in the velocity of the general circulation are clearly not due to variations in the earth's period of rotation but to other factors. Any factor which may affect the velocity of the easterly winds of the lower latitudes or of the westerly winds of the higher latitudes may also cause variations in the deflection of these outflows. In other words, a cyclone of great intensity could increase wind velocity over a wide area and thus cause temporary variations in deflection.

The defective factors which have been considered may be regarded as of minor importance as compared with another, namely, solar activity. The writer has observed that the oceanic anticyclones seem to feed more directly eastward during periods of sunspot minima and more directly into the higher latitudes during years of sunspot maxima. The observations on this point have not covered the full sunspot cycle, but a search of the literature reveals some recent and very interesting investigations made by Clayton.

Clayton (5) investigated the relation between the eleven-year sunspot cycle and changes in atmospheric pressure, noting the departures from the annual means of pressures for about 200 stations scattered over the earth, as given in World Weather Records. When these data were plotted on maps of the world, they showed a tendency toward excess pressures in middle latitudes over the oceans and somewhat lower pressures over tropical lands and oceans at the time of sunspot maximum.

They also showed that the areas of excess pressure over the oceans were displaced northward with each increase in intensity in the sunspot maxima. When there was distinct evidence of excess pressure in middle latitudes over the Atlantic Ocean, there was a deficiency over a large part of the land areas.

These findings suggest an east-west elongation of the Atlantic anticyclone at the time of sunspot minimum. This east-west elongation seemed gradually to develop into a north-south elongation with each increase in intensity in the sunspot maxima. The north-south development over the ocean apparently was associated with a withdrawal of pressure from adjoining land areas.

Clayton's maps showed that the baroplion or area of excess pressure lay in high latitudes during years of high sunspot activity. In 1916-17 the baroplion lay above latitude 65°. It moved to lower latitudes in step with decreasing solar activity, and in 1923 it lay at about 30° latitude. The same progressive movement occurred throughout the eleven-year cycle. The maximum of pressure at Jacobshavn (Greenland) and at Haparanda (North Sweden) coincided with the sunspot maximum, but the pressure maximum occurred successively later at stations to the southwest until at Madeira and Helwan the maximum of pressure occurred at sunspot minimum. Also at Tanana, in Alaska, the maximum of pressure occurred at the time of sunspot maximum and successively later southward to San Diego.

Clayton's findings indicate that there is a real relation between solar activity and the areas of excess pressure that lie in middle and higher latitudes. This writer believes that these areas of excess pressure form in the region that immediately surrounds the ends of the equatorial outflows. These findings, when taken in connection with the writer's observations and interpretation, are illustrated in Figures 1 and 2. Figure 1 shows the approximate positions at the time of sunspot minimum of the three equatorial outflows moving into the northern hemisphere. Figure 2 shows the approximate positions of the same outflows at the time of sunspot maximum. These illustrations seem to show that the equatorial outflows suffer a greater deflection eastward during the period of sunspot minimum and a lesser deflection eastward during the period of sunspot maximum. Here is a variation in deflection which seems to be related to variations in solar activity. The deflection increases as solar activity diminishes and decreases as solar activity increases. In other words, the deflection of the equatorial outflows varies inversely with variations in solar activity.

This evidence suggests that solar activity must be considered as one of the factors which cause the deflection of air currents. The observed variations in solar activity have been relatively slight yet the variations in the deflection of the equatorial outflows have been relatively great. This indicates that solar activity may be a major deflective factor and may rank above the earth's rotation in importance. It is the opinion of this writer that the evidence does not give satisfactory support to the view that air currents are deflected to the right in the northern hemisphere and to the left in the southern hemisphere as a result of the earth's rotation. Much of the deflection that has

formerly been attributed to rotation seems to be due directly to the effects of solar radiation.

A New Interpretation

The exact manner in which solar radiation acts to produce a deflection of air currents is not clear. Only the results are apparent. Variations in solar activity cause corresponding variations in the total output of solar radiation. Increasing solar activity seems to reduce the radiation of those frequencies which affect the velocity of the general circulation, and, consequently, the equatorial outflows move more directly toward the poles. Decreasing solar activity seems to permit a greater radiation of the frequencies which affect the velocity of the general circulation, and the equatorial outflows then develop more rapidly eastward. Air currents may be deflected by several factors, but solar radiation seems to be the primary one. Any factor which interferes with or weakens the effective frequencies of solar radiation before they reach the earth's atmosphere, such as increasing sunspot activity or increasing distance between the earth and the sun, may cause these deflections.

The evidence does not indicate that, when acting alone, either the earth's rotation or solar radiation causes the deflection. It seems that solar radiation and the earth's rotation work together to produce a deflection toward the right in one hemisphere and toward the left in the other, this tending to produce a longitudinal circulation with east-west movements predominating. Factors which weaken solar radiation decrease the deflection, and this tends to produce a latitudinal circulation with north-south movements predominating. These variations in deflection may result in weather and climatic changes of the most astonishing character.

Importance of This Interpretation

This interpretation should lead to a better understanding of the major movements of the general circulation. It suggests that the general circulation may be divided into individual units, all of which are formed according to the same general pattern. Each unit seems to be formed around an atmospheric stream that flows out of the equatorial region and terminates in an anticyclone in middle or higher latitudes. Three such streams move from the equatorial region outward into the higher latitudes of each hemisphere. In the northern hemisphere one stream leaves the equatorial region in the lower latitudes of the eastern Atlantic and terminates in the Asiatic anticyclone. A second stream moves outward from the equatorial region in the lower latitudes of the western Pacific and terminates in the Pacific anticyclone. A third stream moves outward from the lower latitudes of the eastern Pacific and terminates in the Atlantic anticyclone.

The terminal anticyclone of each stream makes contact with the equatorial air in the outflow adjoining it on the east. The line of contact between the cold front of the terminal anticyclone and the warm front of the next outflow becomes a region of cyclogenesis. The cyclones thus formed are carried along in the air-flow of the unit. The air which

leaves the equatorial region and flows into the terminal anticyclone causes that air mass to increase in intensity until a mass of air breaks away from the terminal area and moves into the next unit as a migratory anticyclone. This procedure continues indefinitely. Thus the equatorial outflow with its terminal anticyclone and the attendant migratory pressure formations constitute an individual unit.

The air-flow over the North Pacific ocean furnishes an excellent example of such a unit. This seems to begin in the lower latitudes of the western Pacific and terminates in an anticyclone in the northeast Pacific. The line of contact between the Asiatic anticyclone and the warm air of the Pacific outflow becomes a region of cyclogenesis. The cyclones thus formed are carried along in the air-flow of the Pacific unit, and air masses that break away from the Asiatic terminal area move into the Pacific unit as migratory anticyclones. All migratory pressure formations are carried along in the Pacific outflow directly toward North America. They usually enter the continent from the northwest and continue their movement in approximately a straight line until they drift into the equatorial outflow of the next unit. The migratory formations then move in the direction followed by the American outflow which carries them toward northwestern Europe.

The line of contact between the cold front of the Pacific terminal anticyclone and the warm air of the next unit becomes another region of cyclogenesis. The cyclones which are thus formed usually move from the southwest toward the northeast, being carried along in the air-flow of the unit. This outflow terminates over the eastern Atlantic.

In years of sunspot minima the three terminal anticyclones form between latitudes 30° N. and 40° N. They become elongated in an east-west direction and tend to form a ridge of increased pressure that completely encircles the earth. The migratory cyclones roll rapidly along this ridge on its northern side. This is the typical longitudinal circulation. Increasing solar activity is accompanied by a lesser deflection of the equatorial outflows. Consequently, each terminal anticyclone forms in higher latitudes, and each movement into the higher latitudes is accompanied by lower temperatures in the terminal area. The west-to-east flow into the terminal area changes to a southwest-to-northeast flow, while the west to east flow out of the terminal area becomes a northwest-to-southeast movement. This shows a tendency for the longitudinal circulation to develop into a latitudinal circulation with north-south movements predominating.

Each successive increase in solar activity seems to cause a further decrease in the deflection of the equatorial outflows with a further movement of the terminal anticyclones toward the north and a further development of the latitudinal or north-south circulation. The terminal anticyclones, with their areas of increased pressure, eventually move into the areas that are now occupied by the oceanic areas of low atmospheric pressure. This causes a reversal of pressure conditions, the migratory and permanent cyclones being crowded southward, while high pressure fills the normal low pressure lane. Cyclones can then freely draw in warm, moisture-laden air from low latitudes and carry it directly into the cold front of the terminal anticyclones in high lati-

tudes. This results in unusually stormy conditions with low temperatures and heavy snowfall.

According to the preliminary investigations made by the writer, a continued movement of the terminal anticyclones into the higher latitudes should lead to the formation of cold fronts in low latitudes, possibly accompanied by glaciation in certain areas if geographical conditions were favorable. The complete development of a latitudinal circulation should bring on a period of climatic uniformity.

Conclusions

The importance of the earth's rotation as a deflective factor has apparently been over-emphasized. Air currents may be deflected by several factors. Solar radiation and the earth's rotation, by working together, seem to cause a deflection of the major atmospheric streams that flow from the equatorial region into the higher latitudes. Variations in the effective frequencies of solar radiation permit variations in the deflection of the equatorial outflows. These variations in deflection may result in weather and climatic changes of significance.

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Glacial Lakes Quincy and Eminence

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It is the purpose of this paper to discuss the origin and development of two glacial lakes which occupied portions of Owen, Morgan, Putnam, and Hendricks counties during the Illinoian and Wisconsin glacial stages. The existence of these lakes is indicated by the presence of extensive lacustrine flats in the area under discussion. The presence of these lake plains was recognized by early geologists, but no careful study has previously been made of their areal distribution, origin, or ages. The location of the area discussed in this paper is shown in Figure 1.

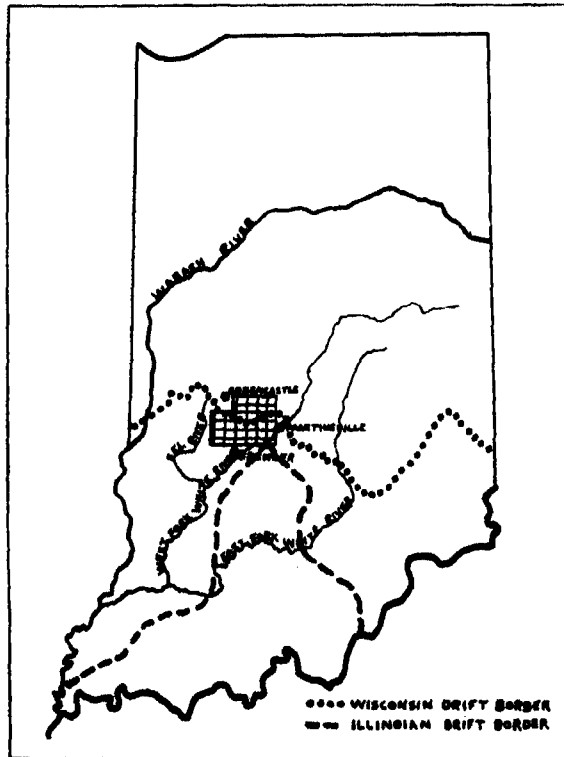


Fig. 1. Outline map of Indiana showing location of area under discussion and its position with respect to the Illinoian and Wisconsin drift borders.

Glacial Lake Quincy

Early descriptions of Lake Quincy.—The name Lake Quincy¹ is proposed for one of these glacial lakes. The site of the lake so named is now marked by a lacustrine plain covering between 40 and 50 square miles lying in portions of northeastern Owen, southeastern Putnam, and western Morgan counties. The name is taken from the small village of Quincy in northeastern Owen County, where extensive portions of the lacustrine plain are still preserved.

Probably the earliest reference to what is here called Lake Quincy was made by Collett.² In his discussion of the effects of the Glacial Epoch upon the geology of Owen County, he says:

"For a probably short time the ice sheet extended over nearly the entire area of the county. . . . It is probable that the foot of the ice flow for a long time lodged, and was heaped up against the ridge running east and west through Spangler's hill just south of Cataract, where the wintry accumulation was melted and discharged down Mill, Rattlesnake, Fish, and Lick creek valleys. . . . Today a cut of less than 70 feet would carry the water of Eel River, above the falls, into Rattlesnake Creek, its old channel. . . .

"That the valleys of Eel, below the cataracts, and White river, below the mouth of McCormack creek, are recent, much more recent than that above, is obvious. They are at once contracted to from one-fourth to one-twentieth their former width, that is, the width of the ancient channel higher up stream. The question at once arises, how was the new channel obtained? During the evident long period that the foot of the glacier rested against Cataract ridge and the highlands in the north part of Monroe county, the continuous retreating and advancing process of the ice scooped out a deep, wide basin in White river, east of Gosport, and north and east of Cataract, just as the basins of the lakes were excavated far below the river and outlet. As the ice by climatic change withdrew to the north, these basins became sluggish streams, or filled by the excessive precipitation common in cold regions, temporary lakes. . . ."

". . . Wells dug in the valley plain, between Quincy and Cataract, in the old river bed leading to the 'flat woods,' and in the wide bottoms above Gosport, indicate beds of laminated sand and muck of lacustral character."

Malott³ in discussing the physiography of the Mitchell plain in this section of Indiana recognizes the existence of extensive lake deposits in this area and states:

"The Mitchell plain north of Ellettsville in northwestern Monroe County has been modified by glaciation. The chief effect of glaciation has been to mantle the rather dissected and locally nearly destroyed plain with glacial material, and eventually farther north to cover over and entirely obscure the plain. Locally, where the plain has been deeply dissected by surface streams, it has been restored to its original level by glacial

¹This represents the formal proposal of the name Lake Quincy for the lacustrine area which occupies portions of northeastern Owen, southeastern Putnam, and western Morgan counties. The naming of this lake area, however, should be attributed to Dr. C. A. Malott, of the department of Geology and Geography of Indiana University. In the *Handbook of Indiana Geology* (P. 210) he refers to this lake region but does not give it a name. He seems to have adopted the name Lake Quincy for this region in his own usage, for A. R. Addington, in a paper on Porter's Cave, which is located just east of the Lake Quincy lacustrine plain, refers to this lake region as Lake Quincy as if it had already been so named. Addington's paper was published in 1927, five years after the *Handbook of Indiana Geology* appeared. It thus appears that the use of the name Lake Quincy had been informally adopted by both Malott and Addington as a result of their verbal discussions of the area. They were both members of the geology staff at Indiana University.

²Collett, John, 1875. *The Geology of Owen County*. Indiana Geol. Surv. Ann. Rept. 7:306-307.

³Malott, C. A., 1922. *Handbook of Indiana Geology*. Pp. 210-211.

material chiefly in the form of lake deposits. Two areas of this kind are of more than ordinary interest. One of these, known as the Flatwoods, lies chiefly in Monroe and Owen counties. . . .

"The other lake area developed in part on the Mitchell plain is quite extensive. It lies along Mill Creek, or Eel River, in northwestern Owen, southeastern Putnam, northwestern Morgan, and southwestern Hendricks counties. It is terminated at its western edge by the double fall of Mill Creek, or Eel River. The lake plain above the fall of Eel River is approximately on the level of the Mitchell plain, which was largely removed in this locality by stream dissection before the region was glaciated. The area of the former lake, or the area affected by ponded drainage conditions, was 50 square miles or more. The altitude of the present lake flat, or lacustrine plain, is 750 to 775 feet. Portions of the Mitchell limestone plain are seen about the margin of the silt-covered area.

"The lacustrine plain above the falls of Eel River is due principally to the obstruction of the pre-Illinoian Mill Creek, or Eel River, in the vicinity of Cataract in northeastern Owen County. The Illinoian glacier completely filled the entrenched valley in this locality to or somewhat above the level of the upland Mitchell plain surface. Following the retreat of the ice the waters in the drainage basin above, which also was probably somewhat modified, found outlet at the level of the bedrock surface high above the old entrenched valley. The waters, however, re-entered the old valley somewhat lower down. Falls were formed where the accumulated waters of the basin above entered the old entrenched valley. In time the basin of the ponded drainage became filled to the level of the bed-rock surface of the stream above the falls, thus giving rise to a lacustrine plain. Inwash in the upper portions of this lacustrine plain has built it up still higher. Portions of it are very flat and poorly drained, as for example along Mud Creek in northwestern Morgan County. This locality west of Monrovia and north of Eminence is known as 'The Lakes' or the 'Lake Country.'

"The falls of Eel River near Cataract are very picturesque. The descent of the stream into the entrenched valley takes place over a stretch of a mile or more, and in a series of rapids, and two falls of approximately 25 feet each, a total descent of nearly 100 feet occurs. Picturesque gorges of several hundred yards in length occur below each of the falls.

"It is not known what influence the Wisconsin glaciation had on the lacustrine plain above the falls of Eel River. Possibly part of the plain itself is due to the Wisconsin glaciation. Few details concerning the region are at present available. A possible connection of the pre-Illinoian Eel River with Rattlesnake Creek has been suggested, but it is not likely that any such connection existed."

Another reference to Lake Quincy is found in Addington's discussion of the relation of Porter's Cave, which lies just beyond the eastern edge of the Lake Quincy lacustrine plain, to glaciation in that area. Addington states:

"The area is marginal to the Early Wisconsin Drift. Along the margins of this drift Glacial Lake Quincy had its inception. Similar to any marginal lake formed along the border of an ice mass, this lake had a number of overflow outlets. The positional relation of the lake flat to the Porter's Cave region is such as to suggest a partial escape for the lake waters in the vicinity of the cave.

"If it is not too much speculating I venture the suggestion that during a short period overflow from the lake was by way of the valley now abandoned and at the same time part of the waters were escaping by subterranean passages along the route of the cave, the subterranean routes receiving more water than they could transmit.

"The abandonment of the valley by the stream and the diversion of the waters to subterranean routes would come as a result of lessened supply due to the lake finding a lower outlet. If this assumption is correct, the drainage condition near the cave had its inception during the Early Wisconsin Glacial Stage.

"Before the exact relation of Lake Quincy to the Porter's Cave region can be ascertained, a detailed study of the lake basin with a view of determining the various overflow outlets will be necessary. This in itself is no small matter. . . ."

¹Addington, A. R. 1927. Porter's Cave and recent drainage adjustments in its vicinity. *Proc. Indiana Acad. Sci.* 36:116-117.

It was for the purpose of supplying more details concerning the Lake Quincy area in order to work out its history that the present study was undertaken.

Description and history of Lake Quincy.—Glacial Lake Quincy developed as a pro-morainal or marginal lake in front of the Illinoian ice sheet due to the ponding of the southwest drainage of Mill Creek.⁵ Mill Creek apparently drained in somewhat the same general direction to the southwest, as at present, prior to the Illinoian glaciation. The damming of Mill Creek occurred in the neighborhood of the village of Cunot in northwestern Owen County. The lacustrine deposits which accumulated in Lake Quincy can be traced down the valley of Mill Creek to a point just about one mile southwest of Cunot in Section 28, T. 12 N., R. 4 W. This morainal dam was approximately three miles below the present site of the upper Cataract Falls on Mill Creek.

The maximum areal extent of Lake Quincy is shown in Figure 2. This map represents fairly accurately the areal extent of Lake Quincy but may not be correct in every detail, as no detailed topographic mapping of the area was done. The map is based upon barometric determinations of altitude. Lake Quincy extended from approximately the Owen-Morgan county boundary on the east westward for a distance of about 12 miles. The northern limits of the lake are not so easily determined for it is partially obscured on the north by deposits of Wisconsin outwash over the Lake Quincy lake deposits. It may have extended somewhat north of the Early Wisconsin moraine (Shelbyville) which crosses Mill Creek near the village of Eminence in western Morgan County. Lacustrine deposits associated with Lake Quincy extend over an area covering between 40 and 50 square miles. It is probable that the lake at no one time covered all of this area. It seems likely that the eastern portion of the lake was the first to develop, and recession of the Illinoian ice front northwestward allowed an expansion of the lake to the west, but as this occurred it is probable that the lake shrank in size at the east. The reason for this conclusion will be pointed out when the outlets of the lake are discussed.

The lake plain which represents the former site of Lake Quincy is most typically developed between the altitudes of 755 to 770 feet but at the eastern and northern ends of the lake the floor of the lake plain rises up to altitudes between 785 and 790 feet. The higher altitudes here are due to inwash of materials from the Wisconsin drift which lies just north of the site of Lake Quincy. This Wisconsin outwash is especially noticeable in the area east of Cloverdale and south of Eminence.

From an altitude of about 790 feet at the east and north the lake

⁵The name Mill Creek will be used in this paper for the stream which flows southwestward through Hendricks, Putnam, Morgan, and Owen counties and joins Eel River near the southwest corner of Putnam County. In many of the older reports the term Eel River was sometimes applied to this stream, but the newer maps designate it as Mill Creek and apply the name Eel River to the stream into which Mill Creek flows. Eel River may be considered as beginning at the junction of Little and Big Walnut Creeks about four miles southwest of Greencastle. Eel River lies a few miles to the west of the area described in this paper.

FIG. 2

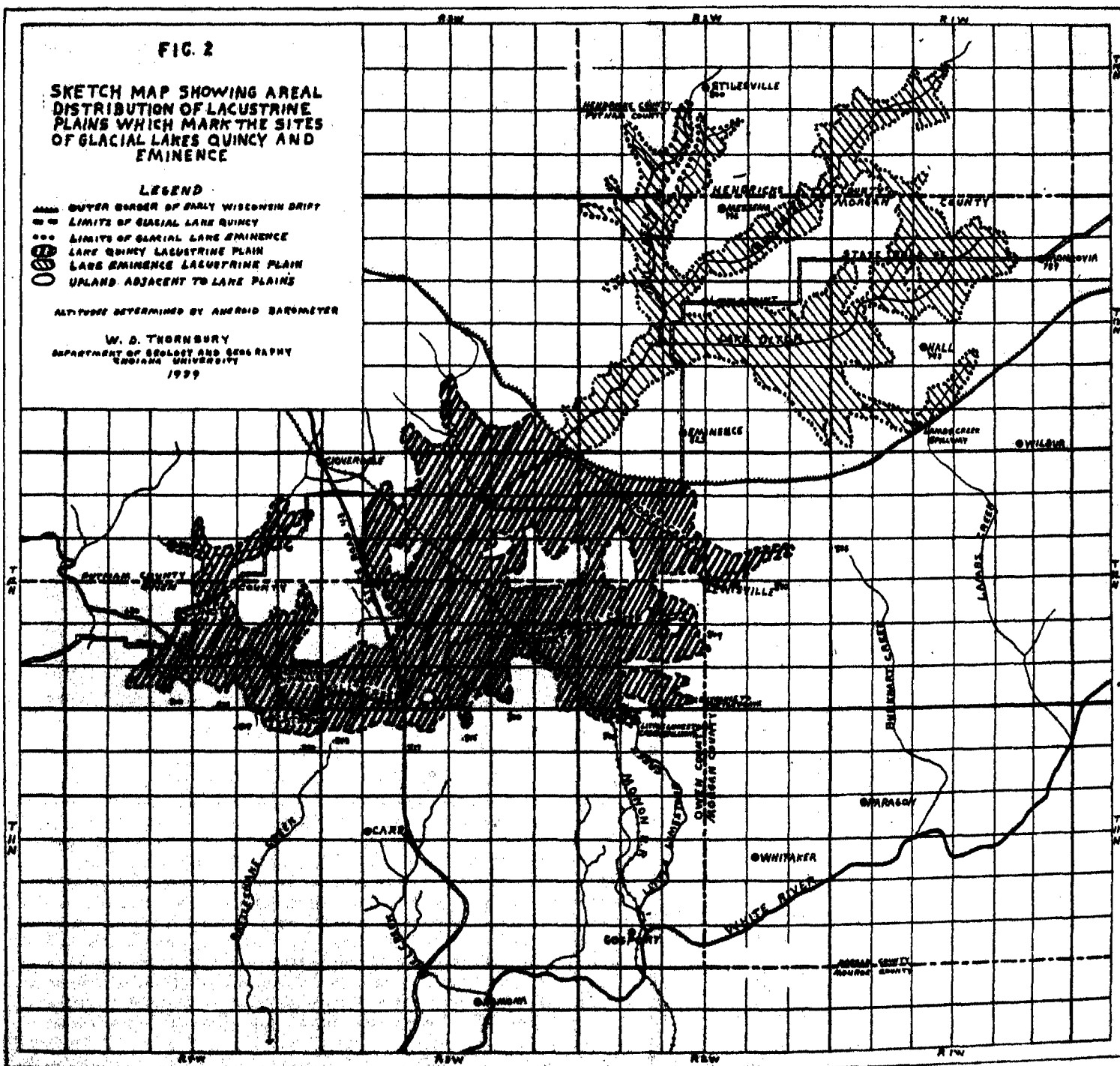
SKETCH MAP SHOWING AREAL
DISTRIBUTION OF LACUSTRINE
PLAINS WHICH MARK THE SITES
OF GLACIAL LAKES QUINCY AND
EMINENCE

LEGEND

- OUTER BORDER OF EARLY WISCONSIN DRIFT
- LIMITS OF GLACIAL LAKE QUINCY
- LIMITS OF GLACIAL LAKE EMINENCE
- LAKE QUINCY LACUSTRINE PLAIN
- LAKE EMINENCE LACUSTRINE PLAIN
- UPLAND ADJACENT TO LAKE PLAINS

ALTITUDE DETERMINED BY AMERID BAROMETER

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DEPARTMENT OF GEOLOGY AND GEOGRAPHY
CHICAGO UNIVERSITY
1929



plain descends to the southwest to an altitude of about 755 feet at its westernmost limits. This is a slope of about 35 feet in a distance of about 15 miles, or a slope of slightly over 2 feet to the mile. The western half of the lacustrine plain has a much slighter gradient than the eastern part. In the section of the lake plain west of Quincy the slope is about one foot to the mile.

Considerable dissection of the Lake Quincy lacustrine plain has occurred in the lower part of the area. Mill Creek has cut out considerable amounts of the silts and clays deposited in the lake. At the point where State Road 43 crosses Mill Creek, Mill Creek has cut its valley down to an altitude of 720 feet, but the terraces which represent the level of the lake plain are at an altitude of 755 feet. However, extensive terraces composed of the lake deposits are preserved along the valley of Mill Creek. In the area above the village of Quincy, in northeastern Owen County, there is preserved an extensive area of the lacustrine plain which is as yet little dissected. A very good cross

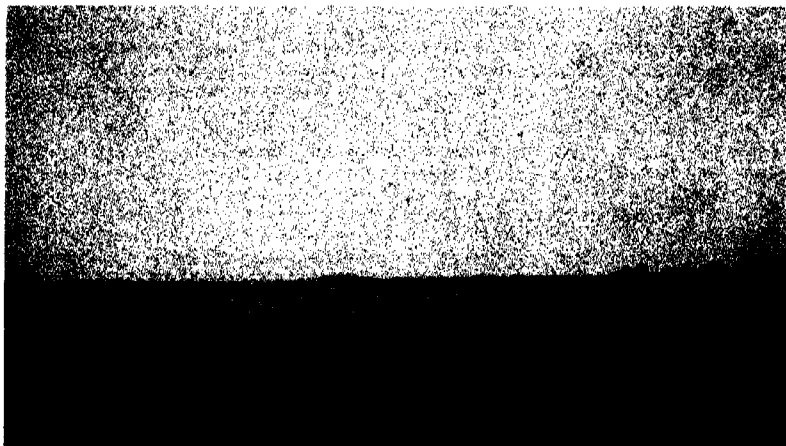


Fig. 3. View of the lacustrine plain of Glacial Lake Quincy about one and one-half miles northeast of the village of Quincy in northeastern Owen County.

section of the lacustrine plain can be obtained by following the route of the Monon Railway from Cloverdale southeastward through Quincy to the southeastern limits of the plain about two and one-half miles southeast of Quincy.

At the northeast the lake plain abuts against the Early Wisconsin (Shelbyville) moraine, and at the east the lake deposits feather edge out against the sink-hole topography of the Mitchell plain. There is already some indication of encroachment of the southeastward drainage into White River upon the drainage of Mill Creek as numerous sink-holes may be seen at the eastern edge of the lake plain. As mentioned above, Addington has suggested that Lake Quincy may have had a partial subterranean outlet through Porter's Cave, but this does not seem likely to the writer for reasons which will be discussed later.

That the age of the Lake Quincy silts and clays is Illinoian, as suggested by Malott, and not Wisconsin, as suggested by Addington, is indicated by the depth to which the lake deposits have been leached of their calcium carbonate. Numerous determinations of the depth to carbonates were made both from exposures of these silts and from borings with a soil auger upon the floor of the lake plain. In all cases the lake silts were leached of their carbonates to depths between 12 and 15 feet. This clearly indicates an Illinoian rather than Wisconsin age for these silts as this depth of leaching corresponds very closely with the depth to carbonates in the Illinoian till of southern Indiana. Previous work by the writer^a has shown that the Illinoian drift in southern Indiana is leached of its carbonates on an average to a depth of slightly over 13 feet, whereas the Early Wisconsin drift is leached of its carbonates to an average depth of about five and one-half feet. There is enough difference between the two that there can be no question as to the Illinoian age of the Lake Quincy deposits.

In Collett's discussion of the Lake Quincy region he suggested that Mill Creek formerly discharged into White River by way of Rattlesnake Creek. His suggested southward outlet of Lake Quincy was across Spangler's ridge, which runs east and west between the present course of Mill Creek and the headwaters of Rattlesnake Creek. Careful barometric determinations of the altitudes along the divide between Mill Creek drainage to the west and the various streams which flow southward into White River have indicated that there could not have been any outlet for Lake Quincy into Rattlesnake Creek. The altitudes along Spangler's ridge are given in Figure 2. The divide between Mill Creek and Rattlesnake Creek is everywhere well above 800 feet. An elevation of about 800 feet would seem to represent about the maximum altitude of the lake in its initial stage since the lake deposits are all below that elevation.

It does appear, however, that for a time Lake Quincy did have an outlet into White River, but it was not by way of Rattlesnake Creek as suggested by Collett, nor does it seem likely that it was by way of the underground route of Porter's Cave as suggested by Addington. It appears likely that during the initial stage of the development of Lake Quincy the lake covered roughly the area east of the village of Quincy. During this stage the lake discharged southeastward into Little Limestone Creek and thence into White River just east of Gosport. There is a very prominent col connecting the southeast end of the lake plain with Little Limestone Creek in the northwest part of Section 5 and the northeast part of Section 6, T. 11 N., R. 2 W. This col occurs at an altitude between 760 and 765 feet and unquestionably was the main, if not the only spillway through which Lake Quincy discharged its surplus waters to the southeast into White River. This spillway is designated as the Little Limestone Creek spillway in Figure 2, and its position is indicated by the arrow pointing toward Little Limestone Creek.

As the front of the Illinoian ice sheet receded to the west the lake expanded westward and eventually found an outlet at a lower altitude

^aThornbury, W. D., 1937. Glacial geology of southern and south-central Indiana. Pub. Indiana Cons. Dept., Div. Geol. P. 49.

to the west near the village of Cunot in northwestern Owen County. This outlet was probably some 10 feet lower than the eastern outlet as the level of the lake flat near Cunot is at an altitude of about 755 feet.

Lake Quincy must have persisted as a lake for a considerable period before lowering of its western outlet resulted in draining, for a considerable thickness of deposits was spread over the floor of the lake. No very accurate data as to the maximum thickness of the lake deposits were obtained, but probably at least 30 feet of silts were deposited in the lower end of the lake. Collett⁷ gives the section shown in Table I from a well in Quincy.

TABLE I.—Section in Quincy Well

	Ft.	In.
Black soil.....	1	08
White and gray clay with crawfish pipes, with little sand, no pebbles.....	10	00
Blue clay, with pebbles.....	8	00
Black mucky clay, with brush and plant remains.....	8	00
Hard pan and fine pebbles.....	8	00
Coarse gravel and boulders, depth unknown.....	3	00
Total	23	08

Information obtained from the farmers in the region about Quincy indicated that they obtained their waters from wells sunk into the deposits over the floor of Lake Quincy. They usually obtained their water from sand and gravels at depths of about 24 feet. The depth to these gravels seemed to increase somewhat toward the west. How thick the gravels are cannot be stated as the wells only go a few feet into them. From the meager field exposures of the lake deposits it appears that the gravel deposits are largely in the eastern end of the lake and that the deposits in the western part of the lake plain are largely silts and clays. However, some sand may be seen around the edge of the lake deposits. One of the best exposures of the lake deposits is obtained where State Road 43 crosses Mill Creek. A portion of this exposure, showing the stratified nature of the deposits, is shown in Figure 4. Portions of the deposits are finely laminated, almost varved. The silts here rest upon glacial till which is slightly below the level of the road. The altitude of the base of the deposits is about 730 feet. This is about 25 feet below the level of the lake terrace here; so there seems to have been about 25 feet of filling in this particular locality.

Near the center of Section 32, T. 12 N., R. 4 W., there is an exposure of lake deposits about 30 feet in depth. It thus appears that 30 feet represents the minimum amount of filling in the lower end of the lake, and it seems likely that it was more than that farther east.

Relation of Cataract Falls to Lake Quincy.—Waterfalls are not very common along the streams of Indiana; so the occurrence of the two falls along Mill Creek suggests something unusual in the history of Mill Creek. While the falls would not attract much attention in some sections of the United States, in Indiana they are unusual, and the owner of the land on which they occur charges ten cents to see them.

⁷Collet, John, 1875. The geology of Owen County. Ann. Rept. Indiana Geol. Surv. 7:819.

Reference has already been made to the fact that the valley of Mill Creek above Cataract Falls is quite different in character from that portion of the valley below the falls. Mill Creek flows as a sluggish stream in that portion of its course which crosses the old lake plain. The present floodplain of Mill Creek at the northern end of the lake plain in southeastern Putnam County is at an elevation of 725 feet. In a stream distance of about 12 miles between this point and upper Cataract Falls, the river falls about ten feet. The upper Cataract Falls

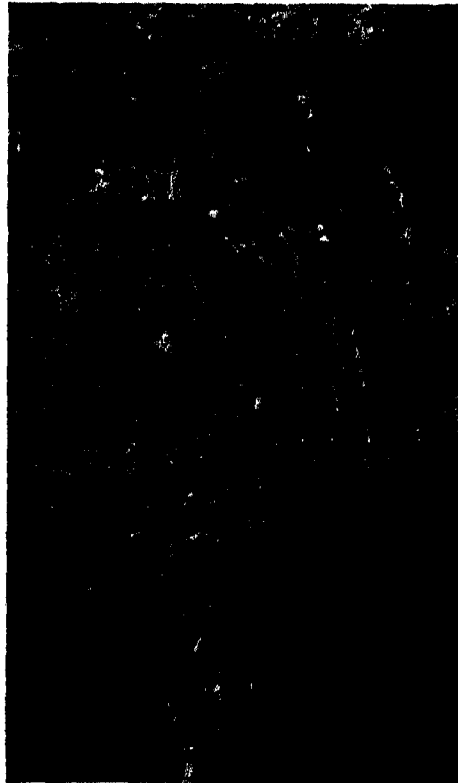


Fig. 4. View of Lake Quincy lake deposits at the bridge over Mill Creek on State Road 43, showing stratified nature of the deposits.

are at an altitude of 715 feet. Below Cataract Falls, the valley of Mill Creek changes into a picturesque gorge, and in two falls of about 25 feet each and a series of rapids the stream falls about 90 feet in a distance of less than two miles. Where Mill Creek joins Eel River, the valley floor is at an altitude of about 620 feet. The gorge below the falls is in places about 200 feet deep, as the surrounding upland gets up to over 810 feet in elevation. The site of the upper falls is shown in

Figure 2. The lower falls is about a mile down the valley from the upper falls.

It is not known for certain what the exact course of Mill Creek was prior to the Illinoian glaciation, but it seems likely that it followed a southwesterly course in the same general direction that it now flows. There seems to be no convincing evidence to indicate that Mill Creek flowed to the south into White River as suggested by Collett. The elevations along Spangler's ridge would seem to preclude this possibility. Doubtless the pre-Illinoian valley was more deeply entrenched in the upland than the present valley is in the portion of its course above Cataract Falls. The advance of the Illinoian ice sheet from the northwest blocked the southwest drainage of Mill Creek and resulted in the formation of Lake Quincy as discussed above. For a time Lake Quincy drained out to the southeast into Little Limestone Creek and thence into White River, but after a time a lower outlet was found



Fig. 5. View of the Upper Cataract Falls.

to the west near the village of Cunot. The lake existed for a long enough time for at least 30 feet of lake silts to accumulate in its basin. Cataract Falls developed at the time that the outlet of Lake Quincy changed from the southeast into Little Limestone Creek to the west into Eel River. Due to the filling which had taken place in Lake Quincy, the new outlet to the west developed at a considerable height above the old valley of Mill Creek, which had been buried under the lake deposits and discharged into the pre-Illinoian portion of the valley below Cataract Falls. After Lake Quincy had disappeared, either through filling of its basin with inwash or through lowering of its outlet, Mill Creek established its present course across the newly exposed lake plain. In the course of cutting out its valley in the lake deposits, Mill Creek encountered a buried ridge composed of the Mississippian limestones of the region, and this buried limestone ridge has pre-

served the falls in Mill Creek. The original site of the falls was probably about two miles farther down stream than the present site. In the time which has elapsed since the draining of Lake Quincy, Mill Creek has removed considerable amounts of the lake deposits, particularly in the western part of the lake plain, where the present valley of Mill Creek is cut from 30 to 40 feet below the upper level of the lake deposits.

Glacial Lake Eminence

Proposal of name.—The name Lake Eminence is proposed for the second of the glacial lakes to be described in this paper. This name is taken from the village of Eminence in western Morgan County. There is no town located upon the lacustrine plain which marks the site of this lake, as is the case with Lake Quincy. The name of Lake Eminence was selected because the lake plain lies just north and east of the town of Eminence, and it also seemed appropriate because the lake was formed back of the Early Wisconsin (Shelbyville) moraine upon which the town of Eminence is located.

Early references to Lake Eminence. One of the earliest references to the lake area which is here designated as Lake Eminence is that of Brown¹, who, in discussing the geology of Morgan County, has the following to say regarding the effect of the glacial period upon Morgan County:

"The glacial period has left its footprints on the surface of Morgan county in a manner that time will hardly efface. Beginning at the Mill Fork of Eel River, a little north of Eminence, there is a valley about five miles wide, extending in a northeasterly direction; crossing the valley of White Lick Creek a short distance north of Mooresville, it passes into Marion county between West Newton and Friendswood, and thence to the valley of White River. From its western origin, to a point in section 1, range 1, township 18, near Monrovia, the valley gradually narrows to a width of about one mile. Originally, this section of the valley was a continuous lagoon, or swamp, locally known as 'The Lake'; but now it is drained westwardly into Eel River, by a public ditch, which has become quite a large creek. On the northern side, the depression of this valley seldom exceeds forty feet below the general level of the country, and the descent is commonly quite gradual. On the opposite side, the country rises from fifty to one hundred feet, and sometimes pretty abruptly. From the watershed near Monrovia, the drainage is eastward, by McCracken's Creek, to White Lick. . . . The topography west of White Lick indicates that this valley was the southern margin of the ice-field for a long time, and received the drainage floods from the disappearing glacier. South of this, I observed no gravel beds, or other evidence of rapid currents that mark a dissolving glacier."

Another reference to this laked region is that of Edmondson², who, in discussing the topography of Morgan County states:

"In the northwest part of the county is found a wide, low, inland valley, locally known as the 'Lakes.' From its outlet, into Eel River, west of Eminence, it extends in a northeasterly direction across Adams Township, touches the northwest corner of Gregg Township and reaches into Monroe Township to a point northwest of Monrovia. Here the wide ridge of rolling upland extending northward from the White River valley, several miles to the south, forms the divide between this and the level country

¹Brown, R. T., 1883. Geology of Morgan County. Ann. Rept. Indiana Dept. Geol. and Nat. Hist. 13:80.

²Edmondson, J. B., 1911. Soil survey of Morgan County. Ann. Rept. Indiana Dept. of Geol. and Nat. Res. 36:84.

farther to the northeast. (Hence the statement by a former geologist (Brown), that the valley extends entirely across Morgan County and joins the White River valley in Marion County, is hardly possible.) The Lake region which was formerly covered with water the greater part of the year was slowly being reclaimed by the growth and decay of vegetation before the advent of the white man. By the use of large dredges and ditches this swamp has subsequently been converted into one of the richest farming regions in the State. . . .

"The lowest part of the valley extends east across the central part of Adams Township, nearly two miles south and approximately parallel to Mud Creek. This was the original outlet to the area, but the gradient being so slight it availed little as an outlet, becoming so filled in that drainage was stopped and the region was covered with run-off from the surrounding uplands a good part of the year. A few years ago, however, this old drainage course was reopened by a large dredge ditch and the drainage difficulties have been solved. The dredge or 'Lake Ditch,' begins in Monroe Township, northwest of Monrovia, and follows the lowest part of the valley in a southwesterly direction across the townships of Monroe, the extreme northwest corner of Gregg, and across the central part of Adams, emptying into Eel River, northwest of Eminence. The ditch is about twenty miles long and is estimated to drain 64,000 acres of extremely fertile soil. Emptying into it is a number of State ditches and many tile drains. In addition to this, the drainage facilities of the region have been much facilitated by the removal of an obstructing dam from Eel River and the straightening of its channel. By these means the water table in this area has been materially lowered although crops still suffer frequently from floods after excessive rains."

Relation of Lake Eminence to Lake Quincy.—The lacustrine area which is here designated as Lake Eminence lies just north and east from the Lake Quincy lake plain, and the two lake plains form a nearly continuous plain extending from northwestern Owen County into southern Hendricks County. They are developed at such similar elevations that it is not at all surprising that they should have been considered by the earlier geologists as part of the same lake plain. The Lake Eminence lake plain was so obviously the site of a rather recent lake that even the early settlers recognized this and referred to the area as pointed out above as "The Lake" or "The Lake Country." The field work done by the writer has convinced him, however, that the two lakes are of different age and even different origin. There are two convincing lines of evidence which indicate that Lake Eminence was formed much later than Lake Quincy. In the first place, the Lake Eminence lacustrine plain is much less dissected on the whole than that of Lake Quincy. Figure 6 is a view of the Lake Eminence plain taken about two miles northeast of the village of Eminence looking northwest across the floor of the lake flat. It has not been dissected at all throughout most of its extent. Only immediately adjacent to Mill Creek has any terracing occurred, where the present floodplain of Mill Creek has been cut from 10 to 15 feet below the original level of the lake bed. The Lake Quincy lake plain, on the other hand, has been noticeably dissected, particularly in its western portion, where Mill Creek has cut down about 30 to 35 feet into the lake silts and removed a considerable volume of the lake deposits. Only the upper end of Lake Quincy resembles the Lake Eminence plain.

More convincing evidence of the later age of Lake Eminence is found in comparing the depth of leaching in the deposits made in the two lakes. As was pointed out above, the Lake Quincy lake deposits have been leached of their carbonates to a depth of between 12 and 15



Fig. 8. View across the Lake Eminence lacustrine plain, about two miles north-east of Eminence.

feet, which indicates an Illinoian age for the lake. However, the deposits laid down in Lake Eminence have been leached only to a depth of between five and six feet on the average. This clearly indicates an Early Wisconsin age for Lake Eminence, as this depth of leaching corresponds closely with that found in the Early Wisconsin drift of the surrounding uplands. Thus, there is no escaping the conclusion that Lake Eminence was separate and distinct from Lake Quincy, which developed during the Wisconsin glacial epoch rather than during the Illinoian.

Description and origin of Lake Eminence lacustrine plain.—The Lake Eminence lake flat is extensively developed in northwestern Morgan, southeastern Putnam, and southwestern Hendricks counties. It covers a total area of approximately 30 square miles. The ponded condition extended up Mill Creek about to Stilesville in southwestern Hendricks County. The most extensive laked area was in the region between Monrovia and Eminence, east of Mill Creek.

The lake plain occurs at an altitude of 760 feet on the east and north and slopes southwestward to an altitude of about 750 feet where it abuts against the Shelbyville moraine. This gives it a downstream slope of about one foot to the mile. It will be noted that this corresponds very closely with the elevation at which the Lake Quincy plain is most extensively developed in its lower portion.

Figure 2 shows the relation of the Lake Eminence lacustrine plain to the Early Wisconsin or Shelbyville moraine upon which the village of Eminence is located and clearly shows that Lake Eminence was formed back of this moraine due to the ponding of the southwest drainage of Mill Creek by this moraine. The highest point on the Shelbyville moraine about one mile east of Eminence has an elevation of 840 feet.

Most of the moraine reaches up to 800 feet or higher. This moraine thus stands from 50 to 90 feet above the lake plain to the north of it. A considerable upland tract which was not covered by the lake lies in the area between Mud Creek and the Lake Ditch. Most of this upland tract lies below 800 feet in altitude.

One break in the upland which lies south of Lake Eminence is found in the south half of Section 29 and the north half of Section 32, T. 13 N., R. 1 W., about one and one-half miles southwest of the village of Hall. Here a col at an altitude of 760 feet may be seen. It appears likely that this col acted as a spillway for the waters of Lake Eminence into Lambs Creek and thence into White River during the early stages of its existence. The lake probably drained out through this route until the morainal dam across Mill Creek was cut lower than the outlet to the southeast, after which Lake Eminence established its outlet to the southwest through Mill Creek.

On the whole, the deposits in Lake Eminence are somewhat more coarse than those in Lake Quincy. Not many good exposures of these deposits are available, due to the undissected nature of the plain, but where they may be seen, as along the Lake Ditch, they exhibit large amounts of sand and gravel and very little of the finer silts and clays which are so abundant in the Lake Quincy region.

Summary

The existence of an extensive area of lacustrine flats in portions of Owen, Morgan, Putnam, and Hendricks counties was recognized by early geologists, but most of the early observers assumed that the lake plain was all developed as part of one lake. The results of the present study indicate that there were two lakes developed in the region, one during the Illinoian glacial epoch and the other during the Wisconsin glacial epoch.

The name Lake Quincy has been given to that portion of the laked region which represents the site of the Illinoian lake. It developed as a pro-morainal or marginal lake around the border of the Illinoian ice sheet and was the result of the ponding of the upper portion of Mill Creek's drainage. During the early stages of its existence it discharged through a spillway into Little Limestone Creek and thence into White River near Gosport. Later in its history a lower outlet was developed at the west into Eel River. The lacustrine plain which marks the site of Lake Quincy covers between 40 and 50 square miles and is most typically developed at elevation between 755 and 770, but at the east the lake plain rises up to as high as 790 feet. There is no evidence to support the idea that Mill Creek prior to the Illinoian glaciation discharged through the present route of Rattlesnake Creek into White River, but it appears to have had a southwesterly course somewhat similar to its present course. Cataract Falls developed at the lower end of Lake Quincy where the post-Illinoian Mill Creek discharged into that portion of its pre-Illinoian course which had not been ponded. The falls have been preserved due to the fact that Mill Creek in excavating the lake silts in the lower part of the lake plain encountered a buried ridge or spur underlain by limestone. The Illinoian age of Lake Quincy is

indicated by the fact that the silts and clays deposited in it have been leached of their carbonates to depths of 12 to 15 feet, an amount of leaching comparable with that found in the Illinoian drift of the nearby uplands.

The name Lake Eminence has been given to the lake which developed just north of the site of Lake Quincy and back of the outer Early Wisconsin moraine which runs through the village of Eminence in western Morgan County. The lacustrine plain which marks its position is typically developed at an elevation around 760 feet, which is so nearly the same elevation as the Lake Quincy plain that it was thought to be a part of the Lake Quincy plain. The younger age of Lake Eminence is indicated by the fact that the lake deposits of this lake are leached to depths of only five to six feet. This depth of leaching corresponds closely with the depth of leaching in the Early Wisconsin drift and indicates that Lake Eminence was developed during the Wisconsin glacial epoch. The slighter amount of dissection of the Lake Eminence plain as compared with that of the Lake Quincy plain also indicates a younger age. It appears that Lake Eminence, during the early stages of its development, drained out to the south through a spillway into Lambs Creek and thence into White River; but it later developed a western outlet, and now the drainage of the lacustrine plain goes to the southwest through Mill Creek. The Lake Eminence plain covers an area of about 30 square miles and represents one of the most fertile soil regions in Morgan County.

Heavy Mineral Assemblages from Upper Cambrian Formations as Exposed at Coon Valley and Victory, Wisconsin

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Introduction

The heavy mineral assemblages here described were extracted from specimens collected by Gilbert O. Raasch and the writer while Raasch was preparing a paper on the Croixian Series in Wisconsin, which was later incorporated in the Kansas Geological Society Guidebook for 1935. The section is a composite of two sections located in the Stoddard Quadrangle just south of La Crosse, Wisconsin. Formations exposed at Coon Valley, 14 miles southeast of La Crosse on U. S. Highway 14,¹ include the entire Galesville member of the Dresbach formation and the Iron-ton member of the Franconia formation through an almost continuously exposed thickness of 100 feet. Formations exposed in a ravine in the Mississippi River bluff 1½ miles north of Victory, Vernon County, Wisconsin, and about 20 miles south of La Crosse² include the Franconia formation with the exception of the lower portion of the Iron-ton member, the Trempeleau formation, and the lower part of the Oneota Dolomite, and another almost continuously exposed thickness of 340 feet.

The relative age and sequence of the rocks exposed in the Coon Valley-Victory section are as follows (4).

	Thickness feet
Victory	
Ordovician	
Beekmantownian series	
Prairie du Chien formation	
Oneota Dolomite—lower 24 feet.....	24.0
Cambrian	
Croixian series	
Trempeleau formation—172.8 feet	
Madison member.....	19.5
Jordan member.....	109.3
Lodi member.....	29.4
St. Lawrence member.....	14.6
Franconia formation—182.1 feet	
Bad Axe member.....	24.1
Hudson member.....	83.0
Goodenough member.....	28.5
Coon Valley	
Iron-ton member.....	46.5
Dresbach formation—87.2 feet	
Galesville member.....	87.2
Total thickness.....	416.1

¹Exact location: Cliff rising above County Highway T in northwest part of Coon Vernon County, Wisconsin; SW¼, NE¼, Sec. 21, T. 12 N., R. 7 W.

²Exact location: Ravine in Mississippi River bluff 1½ miles north of Victory, Vernon County, Wisconsin; SW¼, NE¼, Sec. 21, T. 12 N., R. 7 W.

The purpose of this study is to bring another check to bear upon the boundaries between upper Cambrian formations and their members. To date, these formations have been separated on the basis of paleontology and the megascopic characteristics of the sedimentary rocks. It is hoped that this study of the heavy mineral assemblages will aid in the location of their boundaries.

No heavy mineral studies comparable to this have been made in the region. Earlier work has always dealt with the horizontal and vertical distribution of heavy mineral assemblages within a single formation. Thus, Wilgus (5) has published the results of studies of heavy minerals in the Galesville member of the Dresbach formation in southern Wisconsin. He finds zircon generally dominant with minor amounts of tourmaline and titanium minerals. Garnet is rare or absent except to the west where the member is very thin.

Pentland (2) studied the heavy minerals of the Franconia formation in a triangular area in southwestern Wisconsin, whose approximate apices are Madison, La Crosse, and Prairie du Chien. He found garnet dominant, high tourmaline, and low zircon but made no mention of ilmenite and its alteration products.

Ockerman (1) indicates in his studies of heavy minerals in the Trempealeau formation that garnet is strongly dominant, particularly in the Jordan member.

The writer wishes to acknowledge his indebtedness to Mr. Gilbert O. Raasch, one-time curator of the museum in the Geology Department at the University of Wisconsin, who measured the sections and collected the material for the heavy mineral study. The writer also thanks members of the Geology Departments at the University of Missouri and DePauw University for aid in the preparation of this paper.

Preparation of materials.—Because the strata in the Coon Valley and Victory sections are usually well consolidated, the cementing material being calcareous or dolomitic, it was necessary to remove the cement with hydrochloric acid. The residues were sieved through Tyler screens. Fractions with diameters greater than $1/16$ mm. were immersed in bromoform with a specific gravity equal to that of dolomite (2.9). No record was made of the ratio of the weight of the heavy minerals to the weight of the total sample. The amount of heavy minerals found varied extremely from specimen to specimen but was generally highest in the highly glauconitic green sands of the Franconia formation. After separation, the heavy mineral assemblages were mounted on slides with Canada balsam, either entire or after splitting with a Jones micro-splitter, and were thus made ready for microscopic examination.

Heavy minerals.—The important minerals present in the assemblages studied are: garnet, tourmaline, ilmenite, zircon, leucoxene, anatase, rutile, pyrite, limonite, and a few possible grains of pyroxene.

All garnet grains are characterized by a rough, etched surface and are usually colorless to light pink with occasional red grains.

Tourmaline grains are well rounded, show the usual good absorption, and are dominantly tints of brown or green with a few blue and violet grains. Several opaque tourmaline grains are present.

Ilmenite occurs as well rounded opaque grains which show a coating of gray or brownish-gray leucoxene in reflected light. These grains may often be entirely altered to leucoxene but in that case are almost pure white in reflected light.

Zircon is usually colorless, clear, and rounded enough to eliminate terminal faces but not enough to eliminate the prismatic elongation. Many zircon grains show zoning. An attempt to use zoning as a diagnostic feature of the zircon within a formation produced no results because there is just as great variation in the number of zoned zircon grains from bed to bed in one formation as there is from formation to formation.

Leucoxene and anatase usually occur together, the anatase apparently developing as an alteration product of the leucoxene or along with it and both of them derived from the ilmenite. Leucoxene is generally spongy, may occur in well rounded grains or in irregular masses, has a light gray to white appearance in reflected light, and is at times tinted yellowish-brown by limonite. Anatase usually occurs as well developed, tabular crystals, attached to grains of leucoxene, which show extreme dispersion with nicols crossed. The crystals are usually perfectly developed, indicating that they are authigenic.

Rutile occurs in very small amounts as rounded or somewhat prismatic grains of extremely high relief which are brown or reddish-brown in color and may show striations parallel to the elongation.

Pyrite ordinarily occurs as small, well developed octahedrons or as irregular, granular masses. It is abundant to the point of flooding the heavy mineral assemblages in the more shaly portions of the section and is present to some degree in the more dolomitic or calcareous portions. It is often highly altered to limonite.

Limonite is the most abundant iron oxide encountered. It occurs in extremely irregular opaque to semi-translucent grains which appear brown or yellowish-brown in reflected light. One or two well rounded grains, appearing steel blue in reflected light, may be magnetite but were included with the ilmenite because of the latter's great preponderance in numbers and because of the difficulty in making an exact differentiation.

Two or three grains of a moderate birefringence and relief, which were fairly well rounded, are found scattered throughout the section. They are thought to be pyroxene because of the lack of elongation and the dispersion shown. However, the data are meager since there were only a few grains, none of which showed good optic axis or bisectrix figures.

Heavy mineral assemblages.—The section studied shows the following assemblages of heavy minerals from the top of the section to the base.

The lower four feet of the Oneota dolomite of Ordovician age has the assemblage shown in figure 1. Garnet is outstanding, and tourmaline and zircon are present in small amounts.

The upper ten feet of the Madison member of the Trempealeau formation shows a dominance of tourmaline over zircon and garnet and considerable amounts of ilmenite and its alteration product, leucoxene.

Pyrite is present in very small amounts, probably due to its alteration to the large amount of iron oxide found in this portion of the Madison member (Fig. 2).

The lower eight feet of the Madison member has garnet again present in great abundance with tourmaline and zircon in much smaller amounts (Fig. 3). The Madison as a whole is a fine-grained, dolomitic sandstone 18.5 feet thick with a conglomeratic zone eight feet above its base.

The upper 93 feet of the Jordan member of the Trempealeau formation are consistently high in garnet, usually more than 75%, with tourmaline a very poor second and zircon in extremely small amounts (Fig. 4). This portion of the formation is made up of coarse-grained, poorly cemented sandstone.

The lower 18 feet of the Jordan member are quite shaly. Pyrite is the dominant mineral, varying from 41% to 92% of the heavies (Fig. 5). Garnet is second in importance, and all other minerals are present in extremely subordinate amounts.

The Lodi member of the Trempealeau formation is made up entirely of shale. Pyrite is the dominant heavy mineral, varying from 52% to 100% (Fig. 6). Garnet and other heavies are present in minor quantities.

The St. Lawrence or basal member of the Trempealeau formation is made up of dolomitic shale and sandstone and returns to the dominance of garnet in the heavy assemblages throughout the member, with pyrite a poor second and the appearance of appreciable amounts of ilmenite (Fig. 7).

The upper 51.5 feet of the Franconia formation, which include the Bad Axe member and the upper 28 feet of the Hudson member, are made up of shaly glauconitic sandstone and have a very characteristic assemblage of heavy minerals. Garnet varies from 38% to 69% and ilmenite from 14% to 45%; zircon is third in abundance and tourmaline fourth (Fig. 8).

The lower 54 feet of the Hudson member and the entire Goodenough member of the Franconia formation are made up of rocks similar to the upper portion of the formation but have an entirely different heavy mineral assemblage. Garnet is again the important mineral with zircon and tourmaline alternating in second position (Fig. 9).

The 1.5 feet of the Ironston member of the Franconia formation exposed in the section studied is a dirty, shaly sandstone. It has a heavy mineral assemblage exactly like that of the upper portion of the Franconia formation, the order of abundance being garnet, ilmenite, zircon, and tourmaline (Fig. 10).

Conclusions

Changes in heavy mineral assemblages agree with formation and member boundaries set up on paleontologic and megascopic lithologic criteria except in the case of the three upper members of the Franconia formation. The upper 51.5 feet of this formation have the assemblage shown in figure 8. The lower 54 feet of the Hudson member and the entire Goodenough member have the assemblage shown in figure 9. Therefore, on the basis of heavy mineral assemblages, there would be three members in the Franconia instead of four.

The similarity of assemblages in the upper part of the Jordan and the lower part of the Madison may indicate considerable reworking of the Jordan sandstone before the source of the sedimentary materials changed. This condition is indicated in figures 2, 3, and 4.

Pentland's studies of the heavy mineral assemblages in the Franconia formation show no titanium minerals present. In the Victory section of the Franconia formation the upper 51 feet of the formation and the Ironton member show ilmenite second only to garnet and in amounts varying from 14% to 45%.

A study of heavy mineral assemblages extracted from deep well samples in Indiana might be an aid to more definite correlation of the Cambrian formations that are encountered.

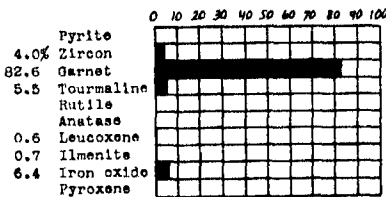


Fig. 1. Oneota Dolomite, Victory, Wisconsin, lower 4 ft.

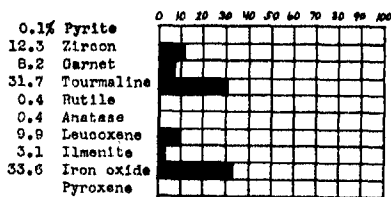


Fig. 2. Madison member of Trempealeau formation, Victory, Wisconsin, upper 10 ft.

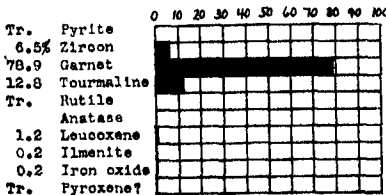


Fig. 3. Madison member of Trempealeau formation, Victory, Wisconsin, lower 8 ft.

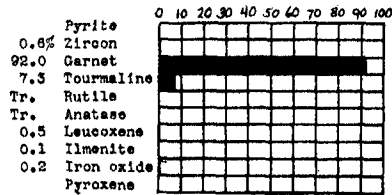


Fig. 4. Jordan member of Trempealeau formation, Victory, Wisconsin, 49 ft. to 74 ft. above bottom of Jordan.

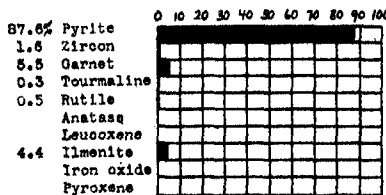


Fig. 5. Jordan member of Trempealeau formation, Victory, Wisconsin, 8 ft. to 10 ft. above bottom of Jordan.

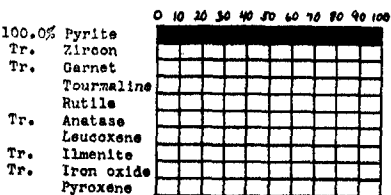


Fig. 6. Lodi member of Trempealeau formation, Victory, Wisconsin, lower 10 ft. of Lodi.

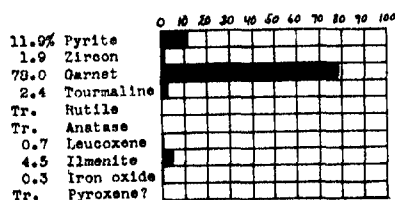


Fig. 7. St. Lawrence member of Trempealeau formation, Victory, Wisconsin, lower 5 ft. of St. Lawrence.

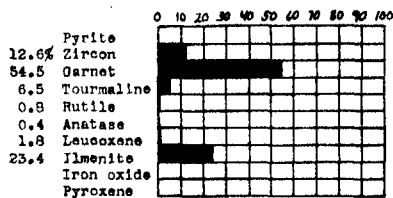


Fig. 8. Hudson member of Franconia formation, Victory, Wisconsin, 54 ft. to 67 ft. above bottom of Hudson.

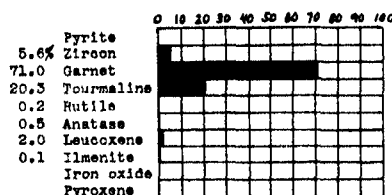


Fig. 9. Hudson member of Franconia formation, Victory, Wisconsin, 8 ft. to 12 ft. above bottom of Hudson.

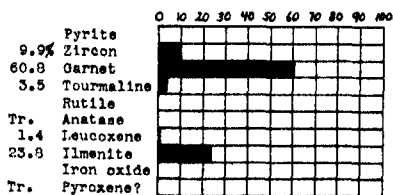


Fig. 10. Ironton member of Franconia formation, Victory, Wisconsin, upper 1.5 ft. of the Ironton.

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An Outline of the Classification of Indiana Soils

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At the last annual meeting of the Indiana Academy of Science the author presented a short paper having a related title, but that paper was devoted to a discussion of historical and philosophical aspects of soil classification and the relationship of kinds of soils to the data of other natural sciences. It contained very little specific descriptive material in regard to either the characteristics of soils or their systematic classification and did not contain a single name of a soil species, genus, or order. Moreover, only an abstract of the paper was published in the Proceedings of the Academy so that whatever repetition may exist in the content of the following paper will be new as far as publication in the Proceedings is concerned.

Obviously, the present paper is largely a new summarization of information which has been published to a considerable extent in the soils literature and is collected from scattered sources and presented here largely because of the interest in this subject expressed by persons who are not soil technicians.

The most complete summary of information about the soils of the United States, which has been published recently, is found in the 1938 Yearbook of the Department of Agriculture, entitled, "Soils and Men." That volume might better have been entitled "Men and Soils," since the first 750 pages contain relatively little soil information and only the last two or three hundred pages are used to cover the entire range of soil conditions for the whole United States. This paper will deal only with the soils of Indiana. In order to orient the material in reference to broader conditions, a few preliminary generalizations may be made.

In this discussion the soil is considered as a natural body which may be classified systematically, and the viewpoint is that the soil is a product of material modified by environmental forces under certain conditioning influences through varying periods of time. This might be stated like a formula

$$S = M \times F \times T$$

Some of the most important environmental forces are included under the term "climate," and from the soils standpoint, there is in Indiana a very limited range of climatic conditions which may be summed up as humid, temperate. There is nothing here like the arid climate which produces alkali soils, or the cold climate which produces tundra soils, or the hot, wet climate which produces lateritic soils as well as other regional soils groups as differentiated by climatic factors.

There is also in Indiana a limited range in the character of geological deposits from which soils have been formed; so it is impossible to have here many kinds of soil found in other parts of the world. In fact, soils identical to those in Indiana could be expected only within areas of a few nearby states where both rocks and climate are comparable. Since there is considerable similarity between the conditions in Indiana

and those in Ohio, Illinois, Michigan, and Kentucky, soil classification is an inter-state problem and has been carried on through cooperation of soil departments in other states as well as with the federal soil agencies which handle inter-state or national soil classification work. Of course, there is some degree of individuality and local independence in the work, and the statements made in this paper consist of the Indiana version of the classification of Indiana soils.

The characteristics of soils grade into each other even more than the characteristics of living creatures intergrade, and, just as some biological taxonomists state there is really no such thing as a "species," it can be said that there is no such thing as a "soil type" which is the unit of classification, and yet the idea which is set up for a soil type or species is a very useful guide in arrangement of information in an orderly manner. The general idea of a "soil type" is that it is a "kind" of soil having relatively uniform characteristics in its various individual areas. The character of a soil is expressed in its gross anatomy and its internal morphology as well as by microscopic or invisible attributes such as physical and chemical constants. The gross anatomy of an individual soil area or its conformation may be described in terms of the surface land form, the area outline or soil pattern, and the nature of the boundary between the true soil and the underlying geological foundation.

Land form specifications for soils may employ geological terms such as till plain, lake plain, moraine, kame, etc. These words are used with their customary meanings; no further explanation will be made here. Land form is also described in simpler terms such as flat, slope, hill, depression, etc., or by giving the percentage of slope as well as the length of slopes, variability in slope, or range of slope. Sometimes the land form is also given in land use adaptation terms.

The outlines of soil areas may be very characteristic of a type and are observed as to whether they are: sharp or indistinct, smooth and regular or irregular, large or small, linear or round, "background" or "detail." On an unlabeled soil map it is often easy to partially identify a soil by its shape alone.

The nature of the contact between a soil body and the geological foundation is much harder to observe than the other dimensions of gross form but can be determined as abrupt or gradual, regular or irregular, distinct or indistinct, etc.

The internal morphology of soils is exhibited in the principal layers or horizons. The main facts to note about the horizons are the number and arrangement in a given soil and thickness, color, texture, structure, consistency, and physical and chemical characteristics of each horizon. There is also the matter of the kind of transition or changes between horizons and the similarities in them.

While the horizons parallel to the land surface are the most conspicuous morphological units, they are, perhaps, not the most important distinctions which can be made. Just as skin, flesh, and bone, which are conspicuous and important layers in the leg of an animal, are perhaps less important in function than the blood vessels which pass through all of them, so the layers of soils may be less significant than the system

of cracks or channels which pass through several different soil layers and function there.

While soils in comparison with geological deposits are highly "organized" bodies, they are distinctly different from living organisms and may be thought of simply as the present product of dynamic, physical, and chemical interactions which are relatively slow in their changes so that the soil characteristics remain about the same for years at a time. Thus they may be classified on the basis of their present characteristics in spite of the fact that they formerly were considerably different and are undoubtedly changing in certain definite directions. At the present time, the classification of soils is based chiefly upon features and relationships which existed when the soil was at equilibrium with nature and these features remain and will persist in many respects in spite of the disturbed natural balance due to agricultural use of the soil. On the other hand, the practical classification does take into account some of the modifications due to agricultural use of the land, the recognition of erosion being the most outstanding instance of this kind. Even in the case of erosion, the scientific classification is based upon the nature of the soil profile which probably existed at a given point even though it has now been largely removed and is well on the way to becoming an entirely different soil in the same location.

Figure 1 shows in tabular form the principal characteristics of the most important soil types in Indiana. It will be noted that from a standpoint of features which can be observed in the surface form and the upper horizons of the soil profiles which reflect most strongly the environmental influences, all of the soils may be grouped under ten generalized concepts, which may be called "general soil profiles." These general profiles are arranged in orderly sequence according to gradations in characteristics, chiefly those dependent upon aeration, oxidation, and drainage. The degree and character of slope also changes systematically in this sequence with certain exceptions. The order of numbering on the columns is irregular because these numerals were established in connection with a somewhat similar table arranged in a different way and have come to have certain significance to soil technicians.

Column No. 6 includes some soils developed on some of the steepest slopes although it is possible to have soils of similar character on somewhat more gentle slopes. However, on the steep slopes the equilibrium between weathering and accumulation versus natural erosion is so much in favor of the latter that the surface material is relatively unmodified and there is little well oxidized soil material present in spite of the excessive surface drainage. In this respect this group of soils is an exception to the rule of arranging the groups in descending order of oxidation.

Column No. 5 includes soils which also are an exception to the general arrangement but for a different reason. They include the best oxidized soils of the whole list, due to the porous nature of the soil and underlying material which may consist of sands and gravels or stones. This well aerated and oxidized condition may occur in soils on topography ranging all the way from steeply sloping to flat land. In the flat land

it is, of course, necessary that the water table be low enough so that the underlying sands or gravel are dry, not saturated with moisture.

The soils in column No. 4 include those which are really the best drained, aerated, and oxidized group in the sequence of *comparable* soils, and their development correlates very closely with a degree of slope which insures rapid run-off of rainfall and good aeration most of the time.

Group No. 3 includes soils of poorer aeration and oxidation than in the case of group 4, due to somewhat less surface slope. There is also an imperfectly drained and aerated condition in the lower subsoil, due either to high water table or some sort of impervious soil or geological layer.

Group No. 2 includes soils with very gently sloping surface or soils which have a relatively high water table resulting in more or less mottled coloration, due to imperfect drainage conditions throughout the profiles.

Group No. 1 includes the flattest soils which are most poorly drained and aerated and most strongly reduced of all soils occupying *convex* land forms. That is to say, although they are frequently saturated, the rainfall has the opportunity to run off them rather than accumulate on the surface in more or less permanent ponds.

The soils of group No. 7 lie on land slopes practically as flat as those of group No. 1, but the land surface has a slightly depressed or saucer-shaped form which tended to collect and hold water which ran off higher land and thus kept the soil under more or less ponded conditions during its developmental period. This excess moisture, through stimulation of increased plant growth and preservation of plant residues, has contributed to the presence of a darker colored surface soil and mottled subsoil colors indicative of poor internal drainage. Some of these soils formerly may have been darker but are now leached because of improved natural drainage or greater age.

Group No. 8 includes soils where the conditions in group 7 have been stronger, more continuous, and more recent so that the surface soils are darker and deeper.

Group No. 9 includes soils developed under the highest degree and most permanent condition of ponding so the surface soils are usually quite dark and deep and subsoils are always very strongly reduced to light gray or drab colors. However, this group includes soils which are still dominantly composed of mineral matter rather than organic matter.

Group No. 10 includes soils which have formed under permanently wet conditions, and the accumulation of organic matter has been so great that the content of mineral matter in the soil has become relatively very low. In other words, the parent material of these soils consists of the remains of vegetation instead of being derived chiefly from mineral and geological deposits.

Soils to be found in any column correspond at least in principle with each other. That is to say, that they represent about the same relative degree of modification as judged by aeration, oxidation, and drainage. However, because of the fundamental differences of the nature of the different parent materials, it is impossible to expect exact corre-

spondence in appearance of all the soils within a given column. For instance, most sandstone soils found in column No. 4 are only reddish-yellow in the best oxidized condition, but some limestone soils placed in the same column may become quite reddish. Also the color of a soil developed under a forest cover is seldom as dark in the upper layers as that of practically the same soil developed under a cover of prairie grass; yet, in both cases the relative degree of oxidation may be practically the same and justify placing them in the same column.

The major groups indicated on the left hand side of the diagram may be regarded as corresponding somewhat to the time factor in soil formation. The group indicated by the letters DDD includes those in which the different layers of the soil profiles seem to be the result merely of deposition as in modern stream alluvium, which remains relatively unmodified and is considered very "young" both from a geological and soils standpoint. The group indicated by ABC includes soils which are usually from relatively young geological materials and are always youthful from the standpoint of soil formation. These letters may be interpreted as indicating that there is a more or less leached surface soil (A) with a subsoil (B) showing more or less accumulation of material leached or transported down from the surface and lying almost directly at depths usually of two to four feet upon relatively unmodified geological material (C). This generalization applies to the soils in columns No. 5, 4, 3, 2, and 1 but not to the soils in column No. 6 which might be called AC soils. This means that they have more or less leached and modified surfaces but no layers of accumulation. Instead, they lie almost directly upon the geological material. The generalization also does not apply very well to soils in columns No. 7, 8, 9 and certainly not to those in 10 because in these depressional soils there is relatively little tendency to develop an upper leached layer and a lower zone of accumulation. Instead, there are upper layers (H) darkened by humus and modified mineral subsoil layers (M) lying on some related or unrelated foundation of geological material (U).

The soils in the group indicated under the symbol ABYC are usually from geologically older material than those in the ABC group and are certainly older from the standpoint of soil development. Part of the greater depth of these profiles is taken care of by an extra layer labeled by the symbol Y which stands for the transition between the main subsoil horizon (B) and the unweathered geological material below. This generalization applies to the soils in columns No. 5, 4, 3, 2, and 1 although to some extent it also applies to those in 7, 8, and 9. The evidence of this greater maturity consists of deeper leaching and more thorough weathering of the soil material.

The soils in the group ABXYC correspond to some extent with those in the preceding general groups, but the depth of leaching is nearly doubled and the degree of weathering is much greater. As previously mentioned, the Y symbol stands for transition between the B and the C, but in this general group, especially in the soils of columns No. 1, 2, and 3, there is an especially modified layer which has been called "clay-pan," "hard-pan," "columnar horizon," etc. This is represented by the symbol X and seems to be the most strongly modified layer of

the entire profile. There is some evidence of an X layer in the soils of column No. 4, but it is doubtful whether it exists in those of column No. 5, and, of course, it does not exist at all in any soil placed in column No. 6 although it may be closely associated and derived from similar materials of the same geological age as the ABXYC soils. It should also be noted in this connection that in regions where ABXYC soils are found, types belonging in the 7 column are rare and types which could be put in 8, 9, or 10 are practically unknown.

The geological material from which soils are formed is one of the most important factors in soil genesis, but it is very difficult to put into precise language or to interpret accurately. It is customary to refer to groups of soils as sandstone soils, limestone soils, or Wisconsin till soils, etc., but such expressions may or may not actually characterize the soil in any significant fashion. Soils are described and identified on the basis of their own characteristics, and sometimes these do not seem to be very closely related to the rock from which the soil is supposed to have been derived. For instance, limestone soils supposedly derived from limestone consisting of 98% calcium carbonate are found to contain no calcium carbonate. It is also true that, although an Ordovician limestone and a Mississippian limestone may apparently give rise to two different soils, the soil differences may not be due to the facts which differentiated the two different geological formations but rather to the nature of the particular minerals which remain after weathering and are actually present in the soils. The word "till" in the field of soils has little meaning if it is defined as "ice-laid," but it is more significant if interpreted as meaning heterogeneous in particle size and lithological composition. It means little in soils to think of "loess" as something which may have been deposited by the wind, but it means a great deal as a material which is now very uniform in particle size and structure.

After the factors of climate, drainage, aeration, time, and parent materials have had their effects as indicated above, the factor of natural vegetation can bring about differences in soils which would otherwise be the same. The most conspicuous case of this kind is the difference between the prairie and timbered soils. In general, prairie soils are darker colored, but they also are less likely to form clay-pans than in corresponding timbered types.

This table, together with the general characteristics considered in its construction, takes care of practically all the soils to be found in the state of Indiana, allowing, of course, for the fact that there may be types of several different textures belonging to some of the soil series named in figure 1.

There are a few cases where additional factors must be taken into account in characterizing some of the minor soils of this region. For instance, there are some so-called alkali spots where there are concentrations of salts which justify classifying the soil as a different type.

All in all, the statement and table presented above should serve as a very good working basis for checking the most important characteristics of any of our soils and in identifying them as belonging to some particular series or at least as closely resembling that series. For instance, anyone, who finds a soil with a color and slope which could be

SOIL SERIES OF INDIANA

MAJOR PROFILE		VI	V	IV	III	II	I	VII	VIII	IX	X
% SLOPE		0-5	0-5	0-5	0-1	0-1	0-1	0-1	0-1	0-1	0-1
ELEVATION ABOVE WATER TABLE		5'+	5'+	3-5	2-3	1-2	0-1	0'-	-1'	-2'	-3'+
OVER FLOW	FREQUENCY	SELDOM	SELDOM	OCCASIONAL	FREQUENT	FREQUENT	FREQUENT	MORE OR LESS FREQUENTLY PONDED AS WELL AS SUBJECT TO HEADWATER FLOODS			
	DURATION	SHORT	SHORT	SHORT	LONGER	LONGER	LONGER				
	DEPTH	ONE TO TEN FEET OR MORE				DEEPER		DEEPEST			
COLOR	SURFACE	DARK	LIGHT	BROWN	BROWNISH BROWN	MOTTLED	LIGHT GRAY	GRAY	DARK GRAY	VERY DARK GRAY	BLACK
	SUBSURFACE	"	"	"	"	"	"	"	"	"	"
	SUBSOIL	LIGHT	"	LIGHT BROWN	MOTTLED	"	MOTTLED	"	MOTTLED	LIGHT GRAY	DARK BROWN
D SWEET LOAMS				GENESEF	EEL					WABASH	
D FROM LIMESTONE AND OLD VALLEY				HUNTINGTON	LINDSEY						
D FROM SANDSTONE AND OLD DRIFT				POPE	PHILO	STENDAL	ATMIND				
% SLOPE		0-25+	0-25+	4-15	2-4	1-2	0-1	0-1	0-1	0-1	0-1
SURFACE DRAINAGE		EXCESSIVE	SLIGHT TO EXCESSIVE	GOOD	MODERATE	SLOW	VERY SLOW	INTERMITTENT	PONDED		
INTERNAL DRAINAGE		GOOD	EXCESSIVE	GOOD	MODERATE	"	"	VERY SLOW			NONE
COLOR	SURFACE	DARK GRAY	BROWN	BROWNISH BROWN	BROWNISH GRAY	LIGHT GRAY	GRAY	GRAY	DARK GRAY	VERY DARK GRAY	BLACK
	SUBSURFACE	VARIABLE	LIGHT BROWN	LIGHT BROWN	LIGHT BROWN	"	"	"	"	"	"
	SUBSOIL	"	BROWNISH BROWN	BROWNISH BROWN	BROWNISH GRAY	"	"	"	"	"	"
	SUBSOIL	"	BROWNISH BROWN	BROWNISH BROWN	BROWNISH GRAY	"	"	"	"	"	"
A	HIGH LINE TILL	TIMBERED	WENDEPH		MIAMI		CROSBY	WETHEL	BROOKSTON	CLYDE	MUCK
	PRAIRIE				PARR						
	HIGH SHALE TILL			ST CLAIR		WAPAROSE				PAULDING	
B	TILL ON LIMESTONE			MILTON		RANDOLPH			HILLDALE		
	HIGH LINE GRAVEL	TIMBERED	RODMAN	FOX	MILL CREEK				WESTLAND	ABINGTON	
	PRAIRIE		WARSAW								
C	LOW LINE GRAVEL		OSHTENO						BRADY	OLYFORD	
	LOW LINE SAND	OLDER	PLAINFIELD		BERNEN				NEWTON	MAUMEE	MUCK
	PRAIRIE	RECENT	BRODSMAN	CALUMET						DEMOTTE	
D	LOW LINE TILL	TIMBERED		LUCAS		HOMER					
	PRAIRIE			JASPER					PENNS- LAND	MAUMEE	
	HIGH LINE SILTS AND CLAYS			MARKLAND		MC GARY		ZIPP	MONTGOMERY	KINGS	
E	HIGH LINE TILL	TIMBERED		RUSSELL							
	PRAIRIE			CARRINGTON	DANA						
	HIGH SHALE TILL			GALENA	OTIS						
F	LOW LINE HIGH SANDSTONE TILL		COLDMA	HILLDALE							
	SHALEY TILL	TIMBERED	TRACY	HANNA							
	GRAVEL	TRANSITION	LYDECK	ALIDA	ARDMORE						
G	PRAIRIE		DOOR						WESTLAND	ABINGTON	
	HIGH LINE GRAVEL	TIMBERED	DELPHI		HOMER						
	PRAIRIE		WEA								
H	LOW LINE GRAVEL SANDS AND SILTS		MARTIN- TILL		WITTAKER	MARTIN- TILL					
	HIGH LINE TILL LOESS		PRINCETON	IDNA	ATYSHIRE				RAGSDALE		
	LOW LINE TILL LOESS		PKE	ALFORD	IVA						
I	LOESS ON SANDSTONE			HOBNER		COR					
	HIGH LINE SHALEY TILL		CINCINNATI	GIBSON	WINDBURG	CLERMONT	BRANCHES- TILL				
	LOW LINE SANDSTONE AND SHALE TILL		CINCINNATI	GIBSON	VIBO						
J	TILL ON LIMESTONE			GRAYFORD							
	TILL ON SHALE			JERRINGS	CANA	WYTCOMB					
	SHALEY LIMESTONE	FARMOUNT		ALLENS	LAWRENCE	WYTHRE					
K	CHERTY LIMESTONE	CORYDON		FREDERICK	BEDFORD	LAWRENCE	WYTHRE				
	PURE LIMESTONE			WYTHRE							
	SANDSTONE LIMESTONE AND SHALE	MUSKOGEE		ZANESVILLE	TILLOT	JOHNSBURG	LICKDALE				
L	LOW LINE SILTS		WINDBURG	OTWELL	WINDSTADT	DUBOIS	ROBINSON	HARRISON			
	LOW LINE STREAM SILTS										
	OLD DRIFT ON SILTS AND CLAYS			WHEELING	WYTHRE	WYTHRE		CHILD			

Fig. 1.

placed in column No. 4, with a well defined leached surface soil, a subsoil with clay accumulation, and with a lower subsoil consisting at a depth of about three feet of a heterogeneous material of different particle sizes and consisting of different minerals, would be justified in saying that this soil is "Miami" or at least "Miami-like."

The names in figure 1 are those of soil "series." A series is something like a genus and may include several "types," differing chiefly in texture of surface soil. A type is regarded as a species.

There is no general agreement as to higher categories in the classification. All of the soil series shown on a single line of the table are grouped as a "catena." Some of the series in any column may be considered a "family." Each complete column includes more or less related soils and the cross table grouping indicated by DDD, ABC, ABYC, and ABXYC each unites soils on a higher basis although no better name than these symbols is now available. Obviously there is still much to be done in perfecting soil classification.

The Sun Spot Cycle and Temperature Departures at Indianapolis, Indiana, 1872-1936

WALLACE T. BUCKLEY, Indiana University

Since the discovery of the periodicity of sun spots by Heinrich Samuel Schwabe, who published his findings in 1843, there has accumulated an enormous volume of literature dealing with investigations of possible relationships between the solar cycle and terrestrial phenomena. Weather variations, climatic changes, plant growth, crop yields, floods, earth magnetism, and human health and behavior have been correlated with the sun spot cycle. The works of Stetson (1) and Clough (2) may be cited as examples of such studies.

The possible effect of sun spots on weather, particularly temperature, has been a popular field of investigation. These investigations seek to establish a definite periodicity in weather variations which will correspond with those of the sun spots. The conclusions of these studies are conflicting. The negative attitude may be illustrated by the following quotation (3): "It is certainly impressive to the thoughtful mind to realize that there is even a slight connection between solar and terrestrial phenomena but the delicacy of this connection is such that it still remains true that the study of meteorology is essentially the study of the earth's atmosphere as acted upon by a constant source of heat, the sun. None of these astrophysical studies should tempt the meteorologist to wander far from the study of the dynamics of the earth's atmosphere and the effect of the oceans and the continents that diversify the earth's surface." The following (4) illustrates the positive attitude. "The principal departures from normal climates which comprise weather are due primarily to a group of periodic variations of the sun's radiations rather than to terrestrial complexities, as has been generally supposed. Sun spots are associated with important modifications of weather not hitherto recognized."

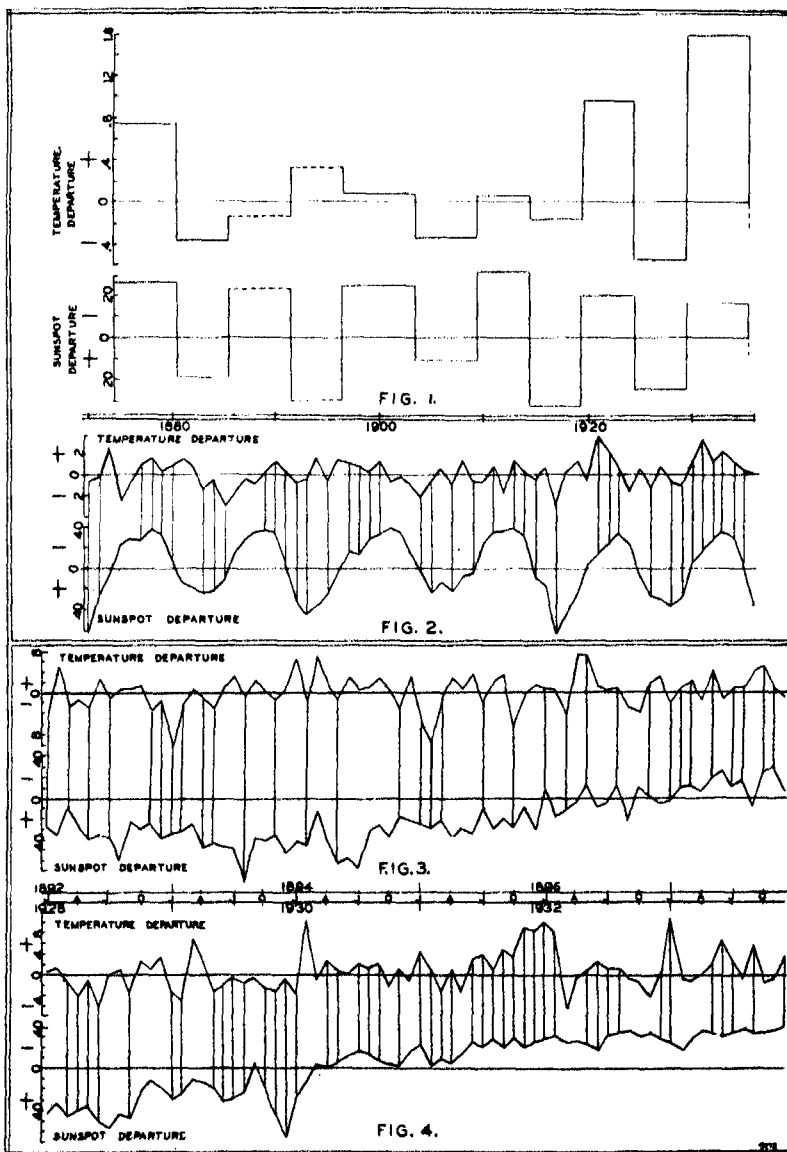
Among those meteorologists and astrophysicists who hold that there is a measurable relationship between sun spot activity and weather variations, there is disagreement as to the nature of the relationship. With regard to temperature, some believe the relationship to be inverse, i.e., an increase in sun spot activity results in decreased temperatures, and a decrease in sunspot activity brings about an increase in temperature. This viewpoint can probably be traced to the works of Köppen and Mielke (5) and has had a more recent application in the work of Henry (6).

This paper investigates the relationships between temperatures for Indianapolis, Indiana, as recorded by the United States Weather Bureau (7) and the Wolf sun spot index numbers (8). These data are plotted to check the assumption that the solar and terrestrial relationship is inverse.

In figure 1 the sun spot index numbers are averaged for the epochs

in which the solar activity was above or below normal. The departures above or below normal are plotted along a base line which represents the average annual sun spot number.

Between 1875 and 1937 there were six epochs in which sun spot



FIGS. 1-4.

activity was below average. The longest period of minimum sun spots, seven years, included the years 1897 to 1903. Two periods, 1910 to 1914 and 1920 to 1924, were but five years each. The epochs of maximum sun spots between 1875 and 1937 were five in number. One epoch, 1904 to 1909, lasted six years. The other four epochs had a length of five years each.

The temperatures plotted in figure 1 are the average of departures from normal for the years included in the epochs of maximum and minimum sun spot activity. For the years 1875 to 1880 the average temperature departure was above normal, and the sun spot activity was below normal. Thus, for this epoch an inverse agreement is established.

For the eleven epochs of maximum and minimum sun spot activity shown in figure 1, there is an inverse agreement between temperature and sun spot departures from normal in nine cases. The two exceptions occurred in the epochs of 1886 to 1891 and 1892 to 1896. This establishes, for Indianapolis temperature departures, an inverse agreement in about 82% of the sun spot epochs studied.

In figure 2 sun spot and temperature departures from average are plotted by years. According to the original assumption, a plus sun spot departure should be associated with a minus temperature departure, and a minus sun spot departure should be associated with a plus temperature departure. Where such agreement occurs in figure 2, vertical lines connect the points of agreement.

In the 65 years between 1872 and 1937, 40 years agreed inversely in temperature and sun spot departures. This is an agreement of about 62%.

It is possible that an increase or decrease in solar activity might affect temperature departures inversely but not sufficiently to bring them above or below average. Thus, there might be an agreement in trend which would not be represented by the vertical lines in figure 2. Such a situation is illustrated in the years 1875 to 1876. Agreement in trend is apparent in 37 of the 65 years charted. This is an agreement of about 60%.

Figure 3 and figure 4 represent sun spot and temperature departures from the monthly averages. They are sections from the chart covering the 780 months between 1872 and 1937. Figure 3 shows the 72 months in the period 1892 to 1897, and figure 4 the 72 months in the years 1928 to 1933. In figure 3 inverse agreement occurs in 34 of the months concerned for an agreement of about 47%. In figure 4 inverse agreement is found in 44 months, an agreement of about 62%.

For the full chart there is agreement for 396 of the 780 months considered. This is an agreement of 51% or only slightly better than might be expected from the operation of the law of chance. The highest agreement occurs in the years 1921 and 1929. Ten of the 12 months in each of these years had temperature departures varying inversely with the sun spot departures. The lowest agreement occurred in 1875 when only two of the 12 months were in agreement.

Agreement in trend between sun spot and temperature departures as revealed by the monthly chart shows that form of agreement in 378 of the 780 months or in about 49% of the cases considered.

Solar activity in any given month might be reflected in temperature departures not for that month but in some subsequent month. The possibility of a lag in agreement was investigated on the monthly chart. Allowing a time interval of one month, it was found that 370 of the 780 months considered agreed inversely for a percentage of about 48. Increasing the lag interval beyond one month did not consistently increase the percentage of agreement.

The following conclusions may be drawn from the above discussion:

1. Temperature departures from the average are most likely to agree inversely with sun spot departures when the period used is the epoch of maximum and minimum sun spot activity. Over a 62-year period at Indianapolis, which covered 11 epochs, there was an agreement of 82%.

2. With shorter time intervals, the year or the month, the agreement becomes less pronounced, that for the year being 62% and that for the month 51%. The monthly agreement is about what might be expected from the operation of the law of chance.

3. Agreement in trend seems to be less significant than the actual agreement in departure from the average.

4. There is no evidence that a lag interval of one month or more increases the percentage of agreement.

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Weathering of Ferruginous Beds in the Pennsylvanian of Greene County, Indiana¹

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The Pennsylvanian in Greene County, Indiana (and in adjoining counties as well), contains occasional thin, hard and tough, ferruginous layers composed largely of iron carbonate and fine silt with minor amounts of calcium carbonate and organic matter. The rock is unusually heavy because of the large amount of iron and breaks down readily under normal surface weathering. Iron carbonate is changed to limonite and is left in successive thin shells concentric to the unweathered kernel of original rock (Fig. 1); calcium carbonate, if present, is dissolved by percolating ground waters and carried away; and the fine silt and organic matter are probably removed as suspended material. Ultimately, much of the iron is released during continued weathering, and it finds its way into contiguous strata and adjacent stream deposits where it becomes both coloring matter and cement.

The weathering cycle begins with circulation of ground water through the jointed layer (Fig. 1) and ends when the original rock has been destroyed completely and its constituents deposited elsewhere. Almost any stage in the cycle may be seen in an extensive outcrop.

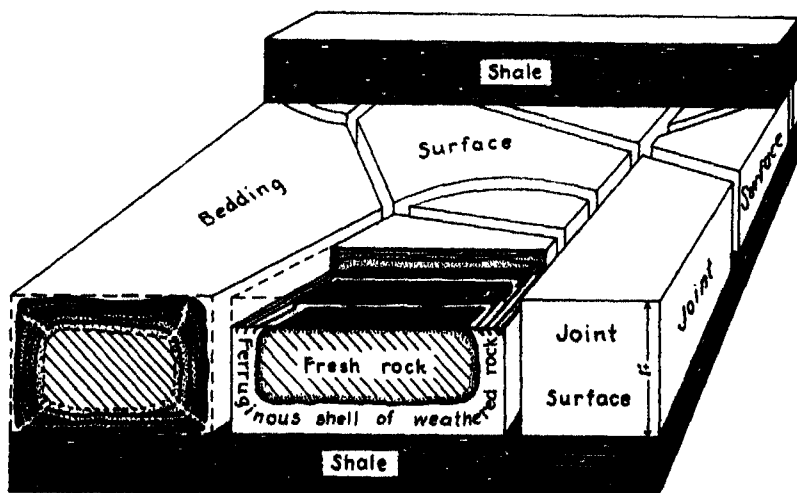


Fig. 1. Diagram showing how a jointed ironband weathers into polyhedra with rounded edges and successive concentric shells of limonite surrounding a core of fresh rock. Sketch based on exposures in a ravine in the N.W. $\frac{1}{4}$ Sec. 6, T. 6 N., R. 4 W., $2\frac{1}{2}$ miles southeast of Bloomfield.

¹Observations on which this discussion is based were made during field work for the Sun Oil Company, Philadelphia, in the summer of 1938. Permission to publish has kindly been granted by the Sun Oil Company.

The ferruginous sediment is believed to have been deposited in a quiet, shallow body of fresh water into which streams and wind were bringing the constituents from the surrounding land surface.

Stratigraphic associations.—The ferruginous rock occurs as thin bands ("ironbands") and zones of concretionary masses ("ironstones") at irregular intervals in the lower 300 feet of the Pennsylvanian in the eastern half of Greene County. The bands and concretionary zones lie in a sequence of sandstones, shales, and thin coal beds, as is apparent from the following sections:

Section in ravine in the N.W. $\frac{1}{4}$ Sec. 6, T. 6 N., R. 4 W., about 2 $\frac{1}{2}$ miles southeast of Bloomfield, Greene County (in descending order).

9. Blue shale weathering to gray clay.....	3'	00"
8. IRONBAND		01"
7. Blue gritless shale breaking into chips and weathering to gray clay (mud)	2'	06"
6. IRONBAND (furnished specimens shown in Figs. 2 and 3).....		01.5"
5. Gritless blue shale.....	1'	00"
4. Iron-stained sandstone with small, kidney-like shale flakes.....		02"
3. Black bituminous sandstone which is bedded, but is tough because of the strong bituminous cement.....	1'	00"
2. IRONBAND, which is well jointed and releases "boulders" on weathering		02"
1. Blue, somewhat sandy shale.....	8'	00" +

(Section bottomed in ravine just below the exposure of ironband No. 2).

Section measured along a ravine in the N.W. $\frac{1}{4}$ Sec. 21, T. 7 N., R. 4 W., just south of Highway 54 and about 4 miles east of Bloomfield, Greene County (in descending order).

6. Thin-bedded sandstone.....	2'	00"
5. Blue gritless shale.....	4'	00"
4. IRONBAND, well jointed.....		02"
3. Coal		04"
2. Underclay		04"
1. Blue, gritless shale.....	4'	04"

(Section bottomed in ravine at base of shale unit No. 1).

Physical and chemical nature of the ferruginous rock.—The rock of the bands and concretionary masses is usually dark colored when freshly broken and is both hard and tough. When thoroughly weathered, it takes on a gray color and may be soft and porous or ashlike. The unusual weight of the rock is at once apparent when a specimen is lifted and indicates a large amount of iron. In the following list the specific gravity of fresh and weathered ferruginous rock is compared with that of several well-known rocks of southern Indiana.

Table of Comparative Specific Gravities

1. Fresh ironband rock, Greene County.....	3.58
2. Fresh ironstone, Greene County.....	3.26
3. Weathered ironstone, Greene County (of No. 1).....	3.02
4. Limonite shell of weathered band (of No. 1).....	2.90
5. Pennsylvanian shale, northwest of Worthington.....	2.47
6. West Franklin limestone, Evansville.....	2.70
7. Lithographic St. Louis limestone, west of Bloomington.....	2.65
8. Beech Creek limestone, Owen County.....	2.62
9. Salem limestone.....	2.48

Layers of the ferruginous rock are always well jointed (Fig. 1) and, as a consequence, are really thin pavements of small rhombic blocks. These blocks have many shapes and are as much as 16 inches in greatest dimension. They slump down over weathered shale slopes as the band breaks up and collect as "boulders" in the ravines below the outcrops of the ironbands. A number of them are shown in Fig. 2, and they will be mentioned again later.

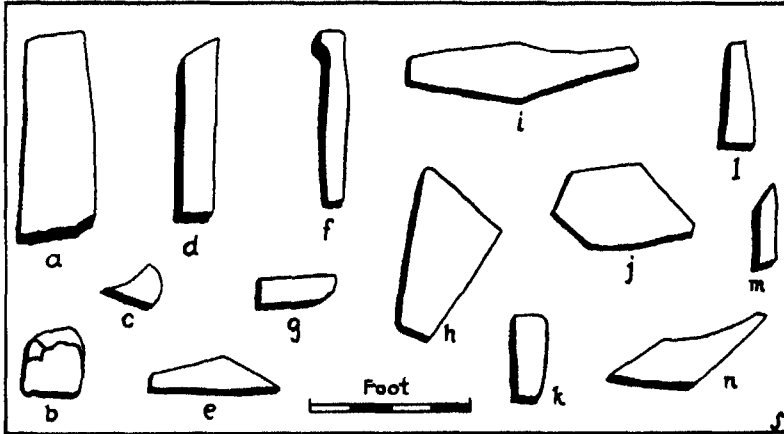


Fig. 2. Joint blocks released from a weathered ironband in a ravine in the N. W. $\frac{1}{4}$ Sec. 6, T. 6 N., R. 4 W., about $2\frac{1}{2}$ miles southeast of Bloomfield. They owe their peculiar polyhedral shapes to joint planes and bedding or separation surfaces. Sketch based on a photograph.

Some of the shales associated with the ironbands contain large discoidal masses, several feet across, that have septarian structure in which the radial cracks are filled with calcite and small, irregular concretionary masses, which resemble sweet potatoes and are solid, dense, and tough, breaking conchoidally.

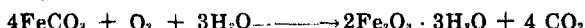
Chemically the ferruginous rock is quite variable in the percentages of the several constituents, and no single analysis conveys a true picture of this variation. The chief constituents, however, are iron carbonate (presumably ferrous carbonate), very fine silt (probably highly quartzose and containing some clay), calcium carbonate, and organic matter. Analyses listed by Logan² show that the iron averages slightly over 55% although the iron content probably varies considerably at different localities.

Weathering of the layers.—The weathering cycle affecting the ironbands begins when the first ground water circulates through the jointed layer and ends when the rock of the layer has been completely destroyed and its original materials scattered over the surrounding countryside. Since the layers usually lie between contiguous shale beds (Fig. 1) and appear to have been jointed almost from the time they were uplifted

²Logan, W. N., 1922. Handbook of Indiana geology. Pp. 761-762.

from the sea floor, they have always furnished excellent channels for circulating groundwater. This water, charged with carbon dioxide and oxygen, circulates through the openings in the ironband, attacking the blocks on the joint faces and bedding surfaces at first and later penetrating them by following cracks that develop along the edges (Fig. 1). In this manner weathering can continue until the entire block has been altered.

In the weathering, the ferrous carbonate is oxidized and hydrated to limonite, which remains as a thin shell around the unweathered core:



Any calcium carbonate present is changed into the bicarbonate and removed in solution:



The silt or clay released during these reactions is carried out, probably as a colloid, or at least in a suspended state. Organic matter may go out in colloidal form, thereby increasing the efficacy of the water to dissolve calcium and ferrous carbonates; some may also act to stabilize any ferric oxide hydrosol that is being removed; and some may be trapped in the limonite shell.

Partial alteration, as shown in Fig. 1, produces rounded blocks composed of a core of unweathered rock surrounded by concentric shells of limonite (Fig. 3). Complete alteration produces rounded or polygonal hollow blocks (Fig. 4), which sometimes have small cores that act as rattles. In some instances, after a layer has been completely altered but before it has had a chance to disintegrate, the hollow blocks are cemented together by limonite into a continuous stratum with a mud-cracked appearance (Fig. 5). When such a layer is cracked open, however, one sees that the individual blocks are hollow, and the cavity

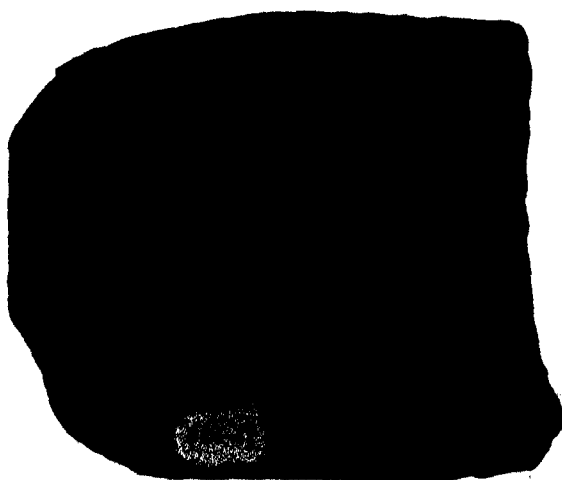


Fig. 3. A partly weathered joint block with rounded edges, showing the gray, unweathered core of fresh rock surrounded by concentric shells of dark, limonitic material which have exfoliated to a considerable degree on the upper side of the specimen. The bedding is in the plane of the page.



Fig. 4. Weathered joint block, now rounded into concretionary form, which has been completely altered with a hollow cavity remaining. The concentric shells are largely limonite that is firmly cemented.

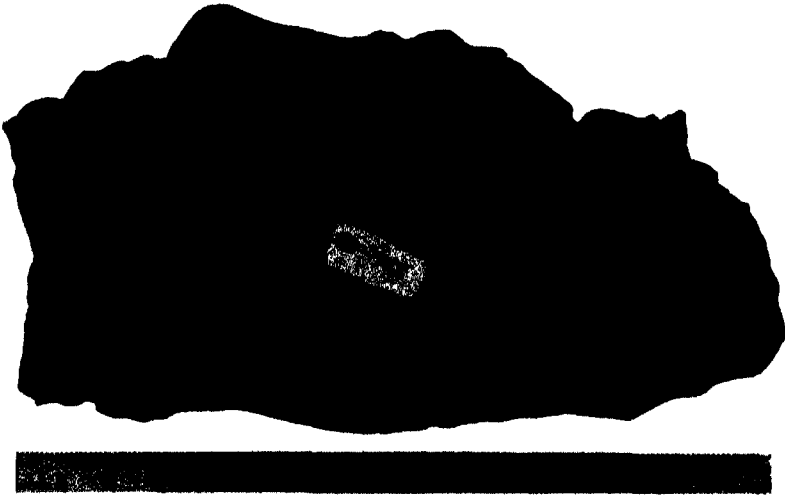


Fig. 5. Weathered ironband in which the original joint blocks have been completely altered and then cemented by limonite into a continuous stratum. Most of the individual blocks are now hollow.

may be partly filled with yellow limonitic powder or it may contain a small fragment of original core, free to move about in the cavity as a rattle.

As the weathered ironband is uncovered and undercut by stream erosion and mass wasting, it disintegrates into the joint blocks (Fig. 2), which move downward to the drainage channels. When these leave the mother ledge, they are usually polyhedral slabs bounded by two smooth,

parallel surfaces—the separation or stratification planes—and a number of plane or curved joint surfaces (Fig. 2). The weaker of these, especially those which are hollow, will soon be broken up by impact. Some will lose the limonitic shell, also because of impact with other boulders, and the core of unweathered rock will then continue as a rounded “boulder” that may be mistaken easily for a limestone boulder. These may persist for long distances from the source. In some instances, only part of the concentrically laminated shell is lost; the rest remains with the core, and the resulting block has a concretionary appearance (Fig. 3).

Regardless of the nature of the ferruginous boulders, however, it seems very likely that sooner or later they will yield their iron to circulating ground waters, and this iron will be removed to become coloring matter and cement in other rocks and rock materials. Cases were observed where such iron had been carried downward into porous sandstones and had cemented them firmly; elsewhere, it had been deposited on stream gravels so that the pebbles and boulders not only were cemented together, conglomerate-like, but they also appeared to be composed of iron. A few taps from a hammer, however, usually sufficed to reveal this iron as a thin coating over the particles.

Conditions of sedimentation.—It may be postulated that the original ferruginous sediment was deposited as a fine silt and clay with a high iron content in a shallow body of fresh water to which it was being brought by streams and wind. Since the iron now exists in the unweathered rock as ferrous carbonate, it may be assumed that the sediment was deposited in a reducing environment. Moore and Maynard² have pointed out that most of the iron transported in river waters high in organic matter is probably carried as a ferric oxide hydrosol, which is stabilized by organic colloids. Some of the iron may also have been dissolved by carbonated ground waters and carried as ferrous carbonate.

If the iron was transported as a ferric oxide hydrosol, it would be co-precipitated together with the stabilizing organic colloids by the negatively charged muds. After deposition the oxide would then be reduced to ferrous carbonate within the mud. If, however, it were carried as ferrous carbonate originally, it would be precipitated directly in that form. This postulated sequence of events agrees best with the observed behavior of iron compounds in fresh water.⁴

During diagenesis, and perhaps to some extent later, the several constituents of the ferruginous deposit were cemented together into the tough rock which may be seen today in unweathered outcrops. The iron-bands, as a consequence, are much more resistant to weathering and erosion than the shales and other contiguous sediments with which they are associated. They became jointed early, and, by the time the rock had been elevated above the water table, channels were in existence for free circulation of groundwaters through the layer. Each block of the mosaic or pavement was subjected to weathering. Hence, each shows in miniature the history of the layer or band as a whole.

²Moore, E. S., and J. E. Maynard, 1929. Solution, transportation, and precipitation of iron and silica. *Econ. Geol.* 24:301.

⁴Hatch, F. H., R. H. Rastall, and M. Black, 1938. The petrology of the sedimentary rocks. George Allen and Unwin (3d ed. rev.). Pp. 147-149.

Calcareous Incrustation Formed on Cascades at the Indiana State Soldiers and Sailors Monument, Indianapolis¹

ROBERT R. SHROCK, BERNARD VONNEGUT, and HENRY F. HERPERS,
Massachusetts Institute of Technology

Several years ago when the cascades at the base of the Soldiers and Sailors Monument were cleaned out thoroughly, a layer of stratified calcareous material, averaging about one inch (25 mm.) thick, was removed from the rounded edges of the six ledges (three in each cascade—see Fig. 1B) over which the water turbulently flows. We propose to describe this incrusting material and discuss some aspects of its formation.

Occurrence of crust.—The cascades on which the crust formed are located at the base of the monument on the east and west sides (Fig. 1D). Each cascade consists of three ledges, the upper of which is a shelf, and the two lower, terraces (Figs. 1A-B). Water is discharged by pumps at the outlet on the uppermost ledge, and it then cascades down across the second and third ledges to the basin whence it is recirculated.

According to Mr. Kurt Vonnegut the crust “formed only on the rounded edges (Fig. 1B) of the cascade ledges, on the vertical faces of the second and third drop, and heaviest of all immediately under the water supply outlet. On the edges of the cascades the crust was thin at the top and increasingly heavier downward to the point of drip (Fig. 1C). There was no sediment on the horizontal surfaces.” The crust was also somewhat thicker on the south sides of the cascades, possibly because the hotter afternoon sun accelerated evaporation and hence increased precipitation of calcium carbonate.

The incrustation formed in a period of about 20 years (1902?-1925?), during which time water from a well at the monument was used. About 1925—the exact time seems to be uncertain—the water supply in the well diminished to such an extent that it had to be augmented by water from the city mains, and within a few years thereafter city water was used exclusively and has continued to be used to the present. There was very little deposition of mineral matter after the change from well to city water because the latter is not nearly as “hard” as that from the monument well. Mr. C. K. Calvert, Chemical

¹We are very grateful to Mr. Kurt Vonnegut for many favors, chiefly the drawings used in Figs. 1A-C and the photograph shown in Fig. 1D, and considerable detailed information about the occurrence of the incrustation. Much of this information was obtained through the kind cooperation of Mr. L. H. Coleman, Supervisor of the Indiana State Soldiers and Sailors Monument. Thanks are also due to Mr. F. C. Jordan, Secretary, Indianapolis Water Company, for information concerning the water consumption at various times and for other courtesies and Mr. C. K. Calvert, Chemical Engineer, for analyses furnished to Mr. Jordan. Finally, we are glad to acknowledge the assistance of Mr. J. Biscoe, Physics Department of the Massachusetts Institute of Technology, who made an X-ray powder analysis of the crustal material.

²Personal correspondence, January 18, 1938.

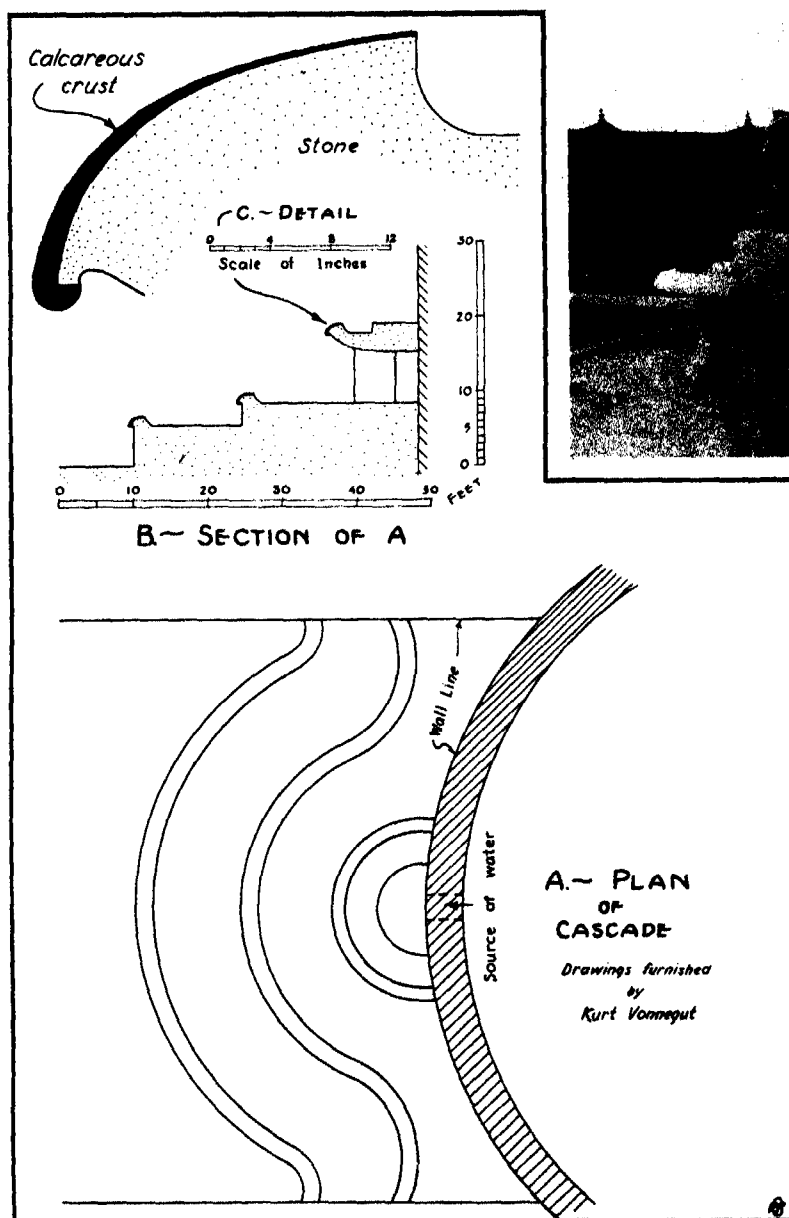


Fig. 1. Sketches and a view of west cascade at the Indiana State Soldiers and Sailors Monument, Indianapolis. (After K. Vonnegut).

Fig. 1D. View of the west cascade, looking northwest, showing the three ledges over which the water flows.

Engineer, kindly furnished the two analyses below, which show the solids in the water from the two sources, with the comment that the monument well "has been out of use for several years" and that "the water is much harder than the city supply and deposition (of calcium carbonate) from it will be at a higher rate, but the city water, under the conditions in the monument basin, will deposit lime."⁸

In the following analyses, Sample No. 1 was taken from the monument well on September 30, 1909, and Sample No. 2 is an average of city water for a seven-year period.

	1. Monument well	2. City water
	(in parts per million)	
Insoluble	10.5	7.8
Calcium (Ca).....	153.2	72.0
Magnesium (Mg).....	46.8	18.0
Sodium (Na).....		27.0
Sodium and Potassium chlorides.....	124.6	
Iron	0.07	0.42
Aluminum (Al)		0.31
Sulphate	192.7	58.0
Chloride	78.0	20.0
Carbon dioxide (CO ₂).....	18.0	
Alkalinity		217.0
Temporary hardness.....	332.0	
Permanent hardness.....	268.0	
Total hardness.....		290.0
Total solids.....	878.0	342.0

During the period when the incrusting deposit was made, it has been reported that the cascades usually operated from 9:00 A. M. to 5:00 P. M. during the warmer months (approximately April 15 to October 15) with a flow of about 4,000 gallons per minute for each cascade.

Apparently the repeated aeration and evaporation of the water, as it flowed turbulently over the cascades, and the consequent evolution of carbon dioxide from this as well as from release of pressure, caused precipitation of the calcium carbonate.

The basins were drained and cleaned bi-monthly during very hot weather and monthly during the remainder of the time the water was flowing.

Nature of crust.—The deposit formed a thin crust over the curved lip of each ledge, and this ranged from 5 to 40 mm. thick with greatest thickness at the point of drip on the ledge nearest the water source (Figs. 1A-C). Chemically, the deposit is rather pure calcium carbonate (95% $\pm$ 5%) with minor amounts of MgO, R₂O, and free C and a trace of sulphate. Mineralogically, it is calcite.

The crust exhibits wavy stratification, which is due largely to undulating films or thin zones and bands of black, carbonaceous matter (Fig. 2). These prominent black bands, numbering at least 16 or 17, are believed to represent the soot, dust, and other impurities which accumulated on the surface of the crust during the winter months when the water was not flowing. The stratification paralleled the surface of

⁸Personal correspondence, January 14, 1938.

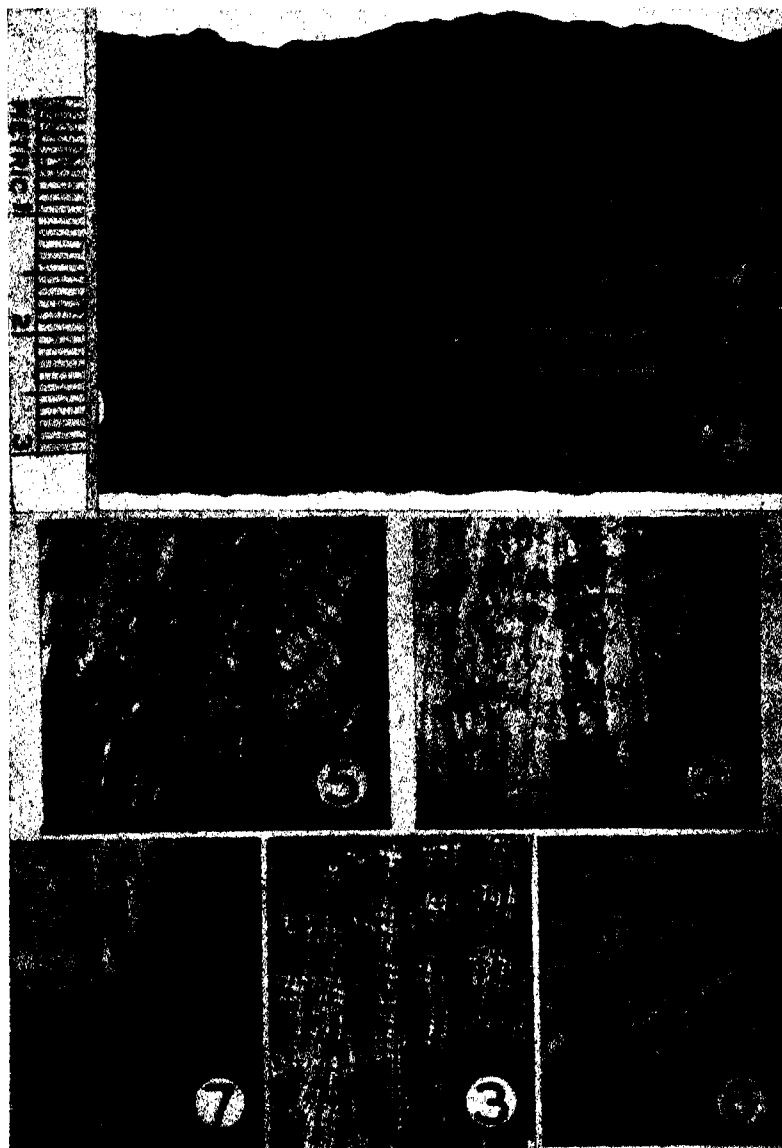


Fig. 2. Polished transverse section of the thickest part of the crust, showing the prominent black bands, between which are many thinner and fainter films of impurities. The more prominent bands are crowded in the lower part and incomplete in the upper.

Fig. 3. Photomicrograph of a small portion of the crust (X 2.5), showing several dark bands and bundles of transecting, acicular crystals of calcite.

Fig. 4. Photomicrograph of a section (X 10) transverse to the crust and parallel

the stone ledge on which it was deposited, and the acicular calcite crystals are disposed essentially at right angles to this surface and the stratification (Figs. 2, 3).

The general surface of the crust is like that of pebble-grained leather but is somewhat undulating with occasional prominent nodular protuberances. Former surfaces appear in transverse section (Fig. 2) as prominent wavy black bands, and the protuberances appear as areas of radial crystallization (Fig. 2).

The fainter and less regular dark films, numbering as many as 10 or 12 between the more prominent bands, may represent dust and other impurities related in some way to the cleaning of the cascades during the summer. The thickness of the material between the more prominent dark bands averages slightly over 2 mm., and this thickness, containing the 10 or 12 films just mentioned, is believed to represent one summer's deposit of calcium carbonate.

The crust is quite porous, especially in the upper third (Fig. 2), where cavities 1 mm. or more across appear and the banding is interrupted and incomplete. The upper part of this imperfect record possibly represents the deposits made during the period when city water was being used to augment the monument well.

The specific gravity of the crust is about 2.50 (2.44-2.59), which is slightly more than that of the Indiana (Salem) building stone (2.48) and slightly less than that of the lithographic St. Louis limestone (2.65).

Formation of crust.—The crust consists of calcite⁴, but the conspicuously acicular structure strongly suggests that the calcium carbonate precipitated originally as aragonite and later recrystallized to the more stable calcite, retaining, however, the acicular character of the original aragonite. This suggestion is supported by the fact that the blade-like crystals of calcite cut across numerous prominent black bands, portions of which may or may not be preserved within the crystals (Figs. 3, 4). Apparently the original crystals—assumed here to have been aragonite—maintained their direction of growth through several summers with seasonal increments added in optical continuity. Then later, when the aragonite changed to calcite, the general crystal form was preserved, and in many instances portions of the numerous films and bands of impurities were preserved. In some cases, however, all traces of the original bands have been eliminated (Figs. 3, 4).

Under the microscope the crustal material is resolved into dark zones and thin bands through which are scattered bits of impurities,

⁴Mr. Jonathan Biscoe, Department of Physics of the Massachusetts Institute of Technology, kindly made an X-ray powder analysis of the material and found it to be calcite; the mineral was also identified microscopically.

with the elongated crystals, showing how the crystals transect several bands of impurities.

Fig. 5. Same as Fig. 4, with nicols crossed, showing the elongated character of the calcite crystals. The matrix is also calcite, with impurities.

Fig. 6. Photomicrograph of a section (X 10) parallel with the crustal surface and transverse to the crystals, showing the latter as rounded polygons which separate readily from each other.

Fig. 7. Portion of crust, X 20, showing same as Fig. 6.

the soot, dust, etc. already mentioned; these zones are transected by bundles of diverging or rectilinear, acicular crystals (Figs. 3, 5). In sections cutting the crystals transversely, the latter appear as rounded polygons and give uniaxial optic axis interference figures, showing that they are elongated parallel to the *c* axis (Figs. 6, 7). The material readily fractures parallel with the crystals which then separate as subprismatic needles with satiny luster.

The deposit obviously was derived from the well water, and it is possible to estimate roughly what fraction of the total calcium dissolved in the amount of water used was precipitated. From its dimensions the total mass of the deposit is estimated as five tons.

Assuming that the well water had the analysis reported (given earlier) and that approximately 3,500,000 gallons were used annually, then as now, it has been calculated that about 5% of the calcium in the water was deposited.

Summary.—This example of rather rapid deposition of calcium carbonate illustrates how that substance may be precipitated from ordinary ground water at normal surface temperatures and pressures. In this instance, the calcium carbonate precipitated from calcium-rich water bearing dissolved carbon dioxide and appreciable amounts of magnesium, sulphate, and chloride ions.

We believe that the carbonate originally precipitated as aragonite and later recrystallized to its present form, calcite. We recognize the possibility, however, that the deposit may have been calcite from the beginning.

The prominent dark bands in all probability represent annual accumulations of winter dirt, made when the cascades were not in operation. The maximum thickness of 40 mm. was deposited in about 3,600 eight-hour days in the 20 (more or less) summers of operation. This rate of deposition—approximately 2 mm. per summer—corresponds fairly well with the observed thickness of material between the more prominent, presumably winter-deposited dark zones. If deposition at this rate were continuous, about 12 mm. of calcium carbonate would be deposited annually.

MATHEMATICS

Chairman: P. D. EDWARDS, Ball State Teachers College

Cora Hennel, Indiana University, was elected chairman of the section for 1940.

ABSTRACTS

A simple interpolation method for unsmooth curves. C. LANCZOS, Purdue University.—If the values $y_0, y_1, y_2, \dots, y_n$ of a function $y = f(x)$, observed at the points $x = 0, 1, 2, 3, \dots, n$, are so unsmooth that their difference table does not converge toward zero, the ordinary interpolation method by means of powers becomes illusory. In this case an expansion into a Fourier series will be more adapted to the nature of the problem. A definite solution of the interpolation problem may be obtained if the Fourier series has a sufficiently rapid convergence, viz., if the number of coefficients practically present in the expansion does not exceed the number $n + 1$ of the given data. In order to satisfy this condition we at first construct the function $\phi(x) = f(x) - (\alpha + \beta x)$, where the constants α and β are determined by the conditions that $\phi(0)$ and $\phi(n)$ shall be 0. We then define $\phi(-x) = -\phi(x)$ and expand $\phi(x)$ into a Fourier series between the limits $x = -n$ and $x = +n$. The construction guarantees the continuity of function and first derivative, and, therefore, sufficient convergence will be achieved for a satisfactory interpolation, provided that n is not too small. The resulting formula follows:

$$f(x) = \alpha + \beta x + \frac{\sin \pi x}{n} \sum_{k=-n}^n \frac{(-1)^k \Phi(k)}{\sin \frac{x-k}{n} \pi}$$

This formula is well adapted to easy numerical computation.

Cubic hypersurfaces symmetric with respect to hyperplanes of a linear system. D. R. SHREVE, Purdue University.—This is a generalization of a paper by Edgardo Ciani, "Sulle superficie algebriche simmetriche," giving a short account of cubic hypersurfaces symmetric with respect to hyperplanes of a pencil, of a net, and of a web, in projective space S_r . The configuration of generalized Eckardt points is considered in detail.

New materials and equipment in mathematics. INEZ MORRIS, Indiana State Teachers College.—A bibliography of equipment and books and magazine articles published during the past year, accompanied by an exhibit of these materials, was prepared. A discussion of these materials included reasons for the type of organization used in the bibliography, the need of teachers for familiarity with the newest materials in mathematics and in related fields, the values of such a bibliography to the busy teacher, an analysis of the relationship of the 1938-1939 texts

to current educational trends, and a brief review and evaluation of several outstanding publications.

On the Dirichlet problem for the equation of the vibrating string. RICHARD J. DUFFIN, Purdue University.—This paper gives a partial answer to the question of the solution being uniquely determined inside the contour if the value of a solution of the wave equation is given on a closed contour. It is shown that the answer hinges on whether or not a certain number defined by the particular contour under consideration is rational or irrational.

Suggestions for the conduct of mathematics clubs. MURET NUGENT, Indiana State Teachers College.—By title.

The Integrating Factor $R = x^m y^n$ for Certain First Order Differential Equations

WILL E. EDINGTON, DePauw University

Consider a differential equation of the form

$$(h_1 x^{\alpha_1} y^{\beta_1} + k_1 x^{\gamma_1} y^{\delta_1})dx + (h_2 x^{\alpha_2} y^{\beta_2} + k_2 x^{\gamma_2} y^{\delta_2})dy = 0, \quad (1)$$

which is not exact. Suppose (1) may be made exact by means of the integrating factor $R = x^m y^n$. In order for $x^m y^n$ to be an integrating factor, certain linear relations must exist among the exponents of x and y , and, when these relations are satisfied, then certain other linear relations exist between m and n in which the h 's and k 's are coefficients. In general, the two equations in m and n are consistent, but under certain conditions these equations may be inconsistent. All these conditions are investigated in this study.

Assuming $x^m y^n$ to be an integrating factor, it follows that, if both members of (1) are multiplied by $x^m y^n$, the equation becomes exact, and then the partial derivative with respect to y of the coefficient of dx is equal to the partial derivative with respect to x of the coefficient of dy . Carrying through this multiplication, equating the partial derivatives, and factoring $x^{m-1} y^{n-1}$ out of all terms of the equation, one has

$$h_1(\beta_1 + n)x^{\alpha_1 + 1} y^{\beta_1} + k_1(\delta_1 + n)x^{\gamma_1 + 1} y^{\delta_1} = h_2(\alpha_2 + m)x^{\alpha_2} y^{\beta_2 + 1} + k_2(\gamma_2 + m)x^{\gamma_2} y^{\delta_2 + 1} \quad (2)$$

Since the members of (2) are identically equal, certain relations must exist among the exponents, and these appear to fall into two cases.

$$\begin{array}{ll} \text{CASE I.} & \alpha_1 + 1 = \alpha_2, \beta_1 = \beta_2 + 1, \quad \gamma_1 + 1 = \gamma_2, \delta_1 = \delta_2 + 1, \\ \text{or} & \alpha_1 + \beta_1 = \alpha_2 + \beta_2, \quad \gamma_1 + \delta_1 = \gamma_2 + \delta_2 \end{array} \quad (3)$$

$$\begin{array}{ll} \text{Then} & h_1(\beta_1 + n) = h_2(\alpha_2 + m), \quad k_1(\delta_1 + n) = k_2(\gamma_2 + m), \\ \text{or} & h_2 m - h_1 n = h_2 \alpha_2 - h_1 \beta_1, \quad k_2 m - k_1 n = k_1 \delta_1 - k_2 \gamma_2 \end{array} \quad (4)$$

$$\text{The equations (4) may be solved for } m \text{ and } n \text{ provided } h_1 k_2 \neq h_2 k_1. \quad (5)$$

$$\begin{array}{ll} \text{CASE II.} & \alpha_1 + 1 = \gamma_2, \beta_1 = \delta_2 + 1, \quad \gamma_1 + 1 = \alpha_2, \delta_1 = \beta_2 + 1, \\ \text{or} & \alpha_1 + \beta_1 = \gamma_2 + \delta_2, \quad \alpha_2 + \beta_2 = \gamma_1 + \delta_1 \end{array} \quad (6)$$

$$\begin{array}{ll} \text{Then} & h_1(\beta_1 + n) = k_2(\gamma_2 + m), \quad k_1(\delta_1 + n) = h_2(\alpha_2 + m), \\ \text{or} & k_2 m - h_1 n = h_1 \beta_1 - k_2 \gamma_2, \quad h_2 m - k_1 n = k_1 \delta_1 - h_2 \alpha_2 \end{array} \quad (7)$$

$$\text{The equations (7) may be solved for } m \text{ and } n \text{ provided } h_1 h_2 \neq k_1 k_2. \quad (8)$$

These two cases in reality are only one, for by interchanging the addends in the coefficient of dy and making the correction in signs, if necessary, Case I reduces to Case II, that is, abstractly there is only one case.

However, the first step to take in the solution of an equation of the form of (1) is to determine whether $h_1 k_2 = h_2 k_1$ or $h_1 h_2 = k_1 k_2$. If so, then no integrating factor of the form $x^m y^n$ may be determined. But then it is not necessary to determine such an integrating factor in order to find the solution of (1), for by making the substitution $y = vx$, the equation (1) reduces to a form whereby the variables may be separated, as will now be shown. The two cases will still be considered in

order to avoid confusion in notation although the work will be carried out in only the one case since the method is the same.

CASE I. Assume $h_1 k_2 = h_2 k_1$. Let $y = vx$. Then $dy = v dx + x dv$. Substituting in (1), imposing conditions (3), collecting like terms, and factoring, one finally obtains

$$\left[(h_1 + h_2)v dx + h_2 x dv \right] \left[h_1 x^{\alpha_1 + \beta_1} v^{\beta_1} + k_1 x^{\gamma_1 + \delta_1} v^{\delta_1} \right] = 0,$$

whence $(h_1 + h_2)v dx + h_2 x dv = 0$. (9)

Solving, one has $x^{\frac{h_1 + h_2}{h_2}} v = C$, or finally $x^{\frac{h_1}{h_2}} y = C$ as the solution of (1).

CASE II. Assume $h_1 h_2 = k_1 k_2$. Imposing conditions (6) and carrying out the work as before, one gets exactly the same result except that k_1 takes the place of h_1 in the coefficient of $v dx$ so that the differential equation becomes

$$(k_1 + h_2)v dx + h_2 x dv = 0, \quad (10)$$

and the solution of (1) is $x^{\frac{k_1}{h_2}} y = C$.

In both cases the algebraic factor $h_1 x^{\alpha_1 + \beta_1} v^{\beta_1} + k_1 x^{\gamma_1 + \delta_1} v^{\delta_1}$ is obtained.

When v is replaced by y/x , this factor becomes $h_1 x^{\alpha_1 + \beta_1} y^{\beta_1} + k_1 x^{\gamma_1 + \delta_1} y^{\delta_1}$, which is the coefficient of dx in (1). Hence, the coefficient of dy may be readily rearranged so as to contain the coefficient of dx in (1), and the resulting differential equation may then be written down by inspection. Thus, any differential equation of the form (1) in which the conditions (3) and (5) or (6) and (8) are satisfied may be solved by means of an integrating factor of the form $x^m y^n$, or it may be solved by inspection when condition (3) or (6) holds but condition (5) or (8) does not hold, respectively.

PHYSICS

Chairman: R. B. ABBOTT, Purdue University

The sectional meeting on physics was attended by about 50 members and guests. Good interest was shown in the papers and discussion. A special feature was the exhibit of the Cenco Company of apparatus and supplies.

James F. Mackell, Indiana State Teachers College, was elected chairman of the section for 1940.

ABSTRACTS

Acoustical properties of wood for musical instruments. R. B. ABBOTT and G. H. PURCELL, Purdue University.—Specimens of wood in the form of rectangular bars 24 in. x $\frac{3}{4}$ in. x $\frac{1}{2}$ in. were tested for their density, elasticity, and internal resistance to motion. The effects of boiling the rods in water, ethyl alcohol, and turpentine and of coating them with oils, varnishes, paints, *etc.*, were observed. A method for separating the internal damping resistance from the air resistance was developed.

The Indiana University cyclotron. FRANZ N. D. KURIE, Indiana University.—The cyclotron now being constructed here is the second largest in the United States. The magnet, weighing 77 tons, is constructed of 0.08 to 0.15% carbon open-hearth steel. With the exception of the poles, all the steel is in the form of slabs 2 in. thick, bolted and welded together. The diameter of the pole tip is 45 in., that of the core is 54 in., allowing a final radius for the ions of about 19.5 in. The over-all dimensions of the magnet frame are 11 ft. x 9 ft. x 4.5 ft. The proportions of the magnet were determined by tests on a small scale model. Energizing coils were wound of ten tons of copper strip ($1\frac{1}{2}$ in. x $\frac{1}{2}$ in.) in 24 pancakes. These coils were entirely homemade. They are to be cooled by water circulating through additional coils of $\frac{3}{8}$ -inch square copper tubing sandwiched between the conductor coils. At 50 KW the model tests indicate a field strength of about 17,000 oersteds for a gap of 6.25 in. This gap is composed of two shimming gaps of $\frac{1}{2}$ in. each and a 5-inch vacuum gap. Preliminary decisions have been reached to feed the radio-frequency power to the dees through a vacuum resonant line. Tests on a full-sized model indicate the vacuum chamber can be made to resonate at about 24 m. This gives a probable output voltage for deuterons of 16 MV. The cyclotron is housed in a room 75 ft. x 55 ft. which is semi-isolated from the new Physical Science Building now being constructed. It is planned to surround the instrument with a water wall in all directions as a protection from neutrons. The control room will be on a mezzanine about 40 ft. from the cyclotron.

Focusing and resonance requirements for the Indiana University cyclotron. ARNOLD F. CLARK and FRANZ N. D. KURIE.—The electric and magnetic fields through which the ions pass in being accelerated in a

cyclotron must satisfy two conditions. One of these is that the angular velocity of the ion must keep the ion in step with the oscillating electrical field, within certain limits. The second condition is that the ions be as well focused as possible in order that the maximum intensity be obtained. In order to facilitate design, these conditions were investigated with models. A two dimensional model of the dees in an electrolyte ray was used to find the best geometry for electric focusing. For dees 3 in. high a separation of 1.5 in. was found to be optimum. Using a twelfth scale model of the magnet, the radial gradient (focusing component) of the magnetic field was measured by two small sensitive search coils bucking each other. Various iron shims were used to determine, to a first approximation, the corrections to the large magnet which will have to be made in order to satisfy both the focusing and relativity resonance requirements for 16 MV deuterons.

The relation between the emission of beta and gamma rays in radioactive substances. A. C. G. MITCHELL, L. M. LANGER, and P. W. MCDANIEL, Indiana University.—The relation between the emission of beta and gamma rays has been studied by measuring coincidences between beta and gamma rays with the help of a coincidence amplifier. The apparatus has a time constant of 0.56×10^{-7} min. The radiations from In^{116} (54 min.), Mn^{56} (2.5 hr.) and Na^{24} (14.8 hr.) have been investigated. In all of the above cases, the method shows that the product nucleus has been left in an excited state by the previous beta ray emission. In the case of Mn, the beta ray spectrum was shown definitely to consist of two groups; that of the other elements was simple. In all cases, gamma-gamma coincidences were found, showing the presence of more than one gamma ray per disintegration. An estimate of the number of gamma ray quanta per disintegration has been made.

Estimates of yet unobserved half-lives of artificial radioactivities. GEORGE DICKSON and E. J. KONOPINSKI, Indiana University.—Advantage was taken of three types of regularities supposed to exist among the binding energies of the stable isotopes to make predictions concerning the half-lives of possible artificial radioactivities which have not yet been observed. First, the "shell structure" periodicity was used. On the basis of the two other types of regularity, nuclei, differing in constitution by a neutron and a proton or by an alpha particle unit, are to be regarded as analogous. The latter, more stringent condition was mainly used, especially because of its apparent confirmation by the incidence of stable isotopes on an isotopic chart. The half-lives of series of known radioactivities, analogous according to the alpha particle criterion, were compared and, wherever regularity was observed, the lives of missing radio elements were estimated in agreement with the regularity. Finally, for the heaviest elements whose stability is most influenced by the coulomb repulsion, series of isotopes symmetrically placed with respect to the most stable isotopes were treated as analogous. This also resulted in some regularities from which predictions of half-lives were made.

Effect of scattering in the source on measurements of beta spectra. E. J. KONOPINSKI, Indiana University.—The approximate evaluation of the effect on the energy distribution of beta particles of scattering in

the source as a linear energy loss is sufficient to show that even the thinnest feasible sources may alter a "Fermi" distribution into a type better represented by a "K. U." curve. The criteria for the use of the empirically found linear range energy relation are fulfilled by portions of the spectra with energy greater than about 200 kv. for source thicknesses, corresponding to losses much smaller than the mean energy of the beta particles. The effect of large angle scatterings of the electrons is to spread the solid angle actually admitted by the measuring devices and thus effectively to thicken the source. The application of these considerations to test the consistency of a given experimental spectrum with a "Fermi" distribution can be carried out analytically. However, the straightforward correction of the experimental data to reveal the true distribution is handicapped by the inapplicability of the method to the lower part of the spectrum.

X-ray diffraction in amorphous rubber. C. M. PARSHALL and K. LARK-HOROVITZ, Purdue University.—Using monochromatic copper or molybdenum x-rays, diffraction patterns of purest latex and smoke sheet have been obtained from samples without any stress. The positions of nearest neighbors and the distribution of atoms along the chain have been determined by Fourier analysis. The number of nearest neighbors is found to be two, in agreement with the prediction from the rubber structure and in agreement with the observations of previous investigators. There are, however, differences between the structure of latex and smoke sheet, which will be discussed in detail in connection with the possible precision of the method.

Test of the Schwarzschild equation for varying development temperatures. LILLIAN THELMA COLEMAN and MASON E. HUFFORD, Indiana University.—The object of this research was to study the effect on the Schwarzschild exponent due to a range of temperature of development, keeping other factors constant as nearly as possible. All the photographic plates were developed, hardened, fixed, and dried under identical conditions; exposure time and temperature of development were the only factors varied. The investigation led to the conclusion that deviation of the Schwarzschild exponent p shows no systematic variation with development temperature. There is, therefore, no one temperature for which the average value of p will more accurately apply than for any other temperature. Therefore, p is not more constant throughout a wide range of exposures for one development temperature as compared with another. In general, then, it may be said that at no one temperature as compared to another does the Schwarzschild equation $E = I t^p$ hold.

Conductivity of Circular Openings in Helmholtz Resonators

R. B. ABBOTT and D. E. ALLEN, Purdue University

In analogy with the flow of electricity in conductors and liquids in pipes, the conductivity of the neck of a resonator is given as (disregarding end effects) $\frac{\pi R^2}{L}$ where R is the radius of the neck and L the measured length. Since the ends of the neck also have an effect on the conductivity, the effective length is greater than the measured length. This added length is a measure of the inertia of the air in the immediate neighborhood of the ends of the neck.

It has been noticed that the expressions for the conductivity of the neck of a Helmholtz resonator as given by different authors do not agree. They do agree in general that it is given by $\frac{\pi R^2}{L_1}$ where L_1 is here the effective length and is given by L plus a suitable end correction. It is in computing this end correction that the discrepancies occur.

Barton¹ gives the end correction as $\frac{\pi R}{4} = .785R$, Morse² gives $\frac{16R}{3\pi} = 1.171R$, Wood³ uses $0.6R$, and Datta⁴ and Olson and Massa⁵ assume no end correction whatsoever. It is correct to make this last assumption if L and L_1 are very large and R is relatively small, but with standard Helmholtz resonators this is never the case.

Rayleigh⁶ takes a circular opening in an infinitely thin wall and finds that the conductivity of this orifice is $2R$. Since conductivity is the reciprocal of resistance, he adds this conductivity to that of a neck of finite length L as follows:

$$\begin{aligned} \text{resistance} &= \frac{1}{2R} + \frac{L}{\pi R^2} \\ \text{conductivity (K)} &= \frac{\pi R^2}{L + \frac{\pi R}{2}} \end{aligned} \quad (1)$$

It is evident that Barton's value of $\frac{\pi R}{4}$ assumes a correction at one end of the neck only. Morse has a correction at both ends, but he has used a value which is approximately correct only when L is very large. Wood's value of $0.6R$ is that given by a correction at one end with no baffle present. Rayleigh's value of $\frac{\pi R}{2}$ assumes a correction at both ends of the neck and holds for small values of L .

In this study to determine the correct value for L_1 , the apparatus consists of the following: (1) a set of ten spherical Helmholtz resonators, (2) a telephone receiver driven by a beat frequency oscillator, (3) a sound meter, and (4) a baffle board about three feet square.

¹Barton, E. H., 1908. A textbook of sound. Macmillan.

²Morse, P. M., 1936. Vibration and sound. McGraw-Hill.

³Wood, A. B., 1930. A textbook of sound. Macmillan.

⁴Datta, A. C., 1917. A textbook of sound. Blackie and Son.

⁵Olson and Massa, 1934. Applied acoustics. Blakiston.

⁶Rayleigh, 1896. The theory of sound. Macmillan.

The resonator neck extends through a hole in the baffle so that its outside end is flush with the top surface of the baffle. The telephone receiver and microphone from the soundmeter, mounted on a swinging boom, are passed back and forth across the opening in the resonator. As the frequency of the receiver diaphragm approaches the resonance frequency of the resonator, an increased intensity will be shown by the soundmeter. When this is a maximum, the two frequencies coincide.

The following table gives the data and results of these experiments. Here the experimental K is found from the resonator formula,

$$N = \frac{C}{2\pi} \sqrt{\frac{K}{V}} \quad (2)$$

where N = fundamental resonance frequency, C = velocity of sound in air, V = volume of resonator, and the theoretical value is from Equation (1).

TABLE I.—Comparison of Theoretical and Experimental Values for K

Volume of Resonator cm. ³	Fundamental Frequency N vib/sec.	Length of Neck L cm.	Radius of Neck R cm.	Experimental Conductivity K c.g.s. units	Theoretical Conductivity K c.g.s. units
6220.0	129	0.25	1.93	3.58	3.57
1180.0	250	0.47	1.49	2.47	2.48
363.0	370	0.37	1.04	1.68	1.70
153.5	503	0.21	0.76	1.30	1.29
98.0	612	0.23	0.76	1.28	1.28
73.0	722	0.22	0.76	1.29	1.28
52.0	858	0.24	0.76	1.28	1.27
39.5	982	0.08	0.69	1.28	1.29
27.5	1080	0.20	0.64	1.08	1.07
21.0	1220	0.21	0.64	1.05	1.06

TABLE II.—End Corrections for Closed Pipes

	N vib/sec.	λ cm.	R_1 cm.	R_2 cm.	d cm
Pipe 1.....	420	62.0	59.2	18.2	2.30
Radius = 2.85 cm.....	480	71.4	51.3	15.6	2.25
Theoretical end.....	540	63.4	45.3	13.6	2.25
Correction $d_1 = \frac{R}{4} = 2.24$ cm.					
Pipe 2.....	420	81.2	59.8	19.2	1.10
Radius = 1.3 cm.....	480	71.4	52.5	16.8	1.05
$d_1 = 1.02$ cm.....	540	63.6	46.7	14.9	1.00
	600	57.2	41.9	13.3	1.00

From this table it is evident that Rayleigh's value for the correction is right, but the question arises as to whether or not it is the same at both ends of the neck. It is necessary to make the obvious assumption that the outside end correction would be the same for a "closed" pipe as for a resonator. This outside correction for the pipe can be found since there is no inside correction; by taking the difference between this value and Rayleigh's value for the resonator, the inside end correction for the resonator can be obtained.

To determine this outside end correction, two pipes of different radii are used. One end of each is closed with a rubber stopper, which can be moved to vary the length of the pipe. The rest of the equipment and procedure are the same as described before.

Two resonance points R_1 and R_2 are found in each of the pipes for each frequency

$$R_1 = \frac{3\lambda}{4} - d \quad (3)$$

$$\text{and} \quad R_2 = \frac{\lambda}{4} - d \quad (4)$$

where λ is the wave length of the sound from the diaphragm and d is the experimental end correction.

Table II shows that the experimental and theoretical values for the end correction of the pipes check within experimental error. From this it can be assumed that the end correction of a resonator is evenly divided between the two ends of the neck when a baffle is used.

The Characteristics of a Low Voltage Arc in a Magnetic Field

A. GUTHRIE and J. O. HANCOCK, Purdue University

For many disintegration experiments, as well as for other investigations, it is advantageous and often essential to have available an intense positive ion beam. During the last few years, the low voltage arc type of ion source has come into general use, for example, the arc sources of Tuve and Hafstad¹ and Zinn.² Livingston³ recently adopted a modified Tuve and Hafstad arc source for use in the cyclotron. Following the work of Livingston, an arc of essentially the same type as that which is to be described was installed in the Purdue cyclotron. In order to investigate the properties of the arc, an experimental arrangement was constructed. The important feature of this arrangement is the use of a magnetic field to concentrate the discharge into a capillary.

The essential features of the experimental arc are shown in Fig. 1.

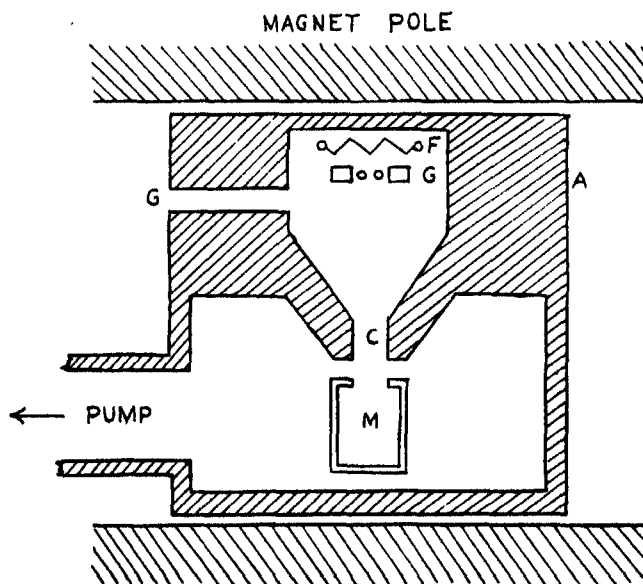


Fig. 1. Sectional drawing of the low voltage arc.

¹Tuve, M. A., O. Dahl, and L. R. Hafstad, 1935. The production and focussing of intense positive beams. *Phys. Rev.* 48:241.

²Zinn, W. H., 1937. Low voltage positive ion source. *Phys. Rev.* 52:655.

³Livingston, M. S., M. G. Holloway, and C. P. Baker, 1939. *Rev. Sci. Inst.* 10:63-37.

A is a brass housing which serves as an anode for the discharge. The grid G, which consists of two 20 mil tungsten wires, parallel to each other and soldered across a rectangular hole cut in a copper disk, was inserted in order to determine whether it would have any effect on the characteristics of the discharge. The canal C is threaded so that capillaries, ranging in diameter from 20 mils to 200 mils, can be used. Hydrogen gas is admitted into the arc region through the inlet G, the flow of gas being controlled by a needle valve. Filament leads, grid, Faraday cage, and brass housing are all water-cooled. The magnet used gives field strengths up to 2500 gauss over an air gap of $3\frac{1}{2}$ inches. The filament is heated by two 6-volt storage batteries connected in parallel. The arc voltage is obtained from a 220 volt D.C. line; the voltage for the Faraday cage is supplied by a rectifier unit. The pumping system consists of a Cenco megavac forepump and a modified Hickman oil diffusion pump, having a pumping speed of about 20 liters of air per second at a pressure of 10^{-4} mm. Hg. The discharge is struck between the filament F and the brass housing. The Faraday cage M is used to measure the strength of the ion current which issues from the capillary due to the action of the magnetic field.

Oxide coated and tungsten filaments have been used in this type of arc. The oxide coated filaments were made from platinum gauze having 70 wires per inch, the diameter of each wire being 0.003 inches, and were coated with a suspension of barium-strontium carbonates. The filament consisted of four layers of the gauze, a short length of 20 mil tungsten wire being spot-welded to each end perpendicular to its length to serve as a lead. The tungsten filaments were made of 20 mil wire in the form of a cone, with the apex of the cone directed towards the capillary.

The principal disadvantage of the oxide coated filament lies in the fact that the coating is removed in a relatively short period of time. The life of the coating was found to decrease with increased magnetic field strength, arc drop, and arc current. This can be explained by the fact that the positive ions in the arc region are accelerated towards the filament by the electric field and follow spiral paths due to the effect of the magnetic field. The destruction of the coating is believed to be due to bombardment of the filament by these positive ions. With an arc current of 1 ampere, a pressure in the arc region of about 3×10^{-3} mm.Hg., and a magnetic field strength of 2000 gauss, the average life of a coating was about 20 hours. A tungsten filament can only be destroyed by actually raising its temperature beyond the melting point. Since the filament must be maintained at a temperature near its melting point for large electron emission, any slight change in filament current or arc current is likely to melt it. Also, at high values of magnetic field strength the force exerted by the magnetic field on the turns of the filament tends to short circuit them. In general, a tungsten filament will give longer service than an oxide coated platinum filament, but more precautions are necessary in its use.

In the case of an oxide coated filament, the volt-ampere characteristic of the discharge (see Fig. 2) indicates operation far from saturation and, therefore, the presence of a double sheath in front of the filament.

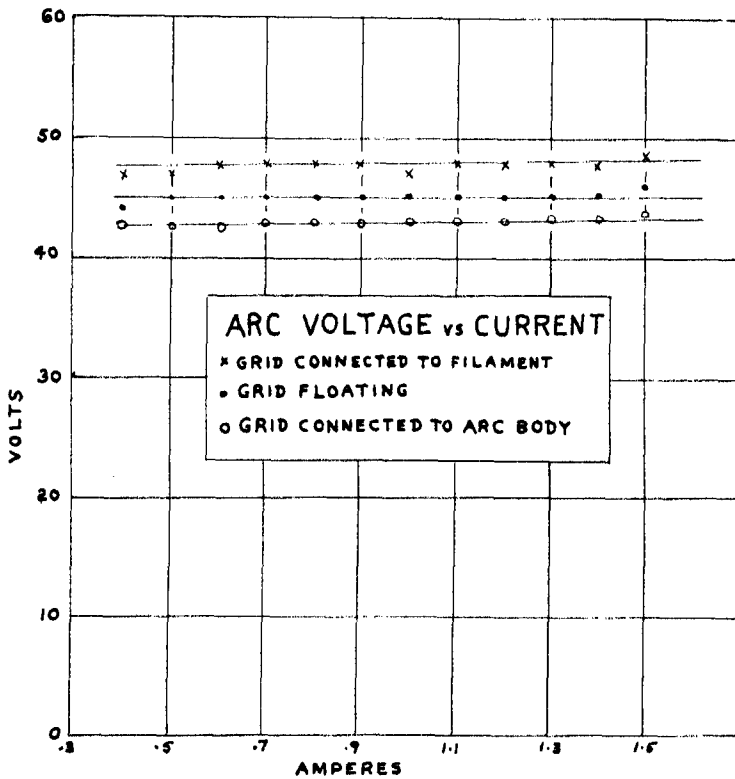


Fig. 2. Volt-ampere characteristics of the arc taken with an oxide coated filament at a pressure of 2.9×10^{-7} mm.Hg and a magnetic field strength of 1000 gauss.

It is to be observed that the manner in which the grid is connected has little effect on the characteristic. This can be expected if the grid behaves as a probe in the plasma of the arc. If a double sheath exists in front of the filament, it is to be expected that a change in magnetic field strength will not affect the characteristic of the discharge. The experimental results show that the arc drop is independent of the magnetic field strength.

The volt-ampere characteristic for the discharge with a tungsten filament is shown in Figure 3. The falling part of the curve shows that the filament is supplying a sufficient number of electrons to maintain a double sheath. The rising portion of the curve suggests that the filament is now unable to satisfy the demand for electrons and, therefore, the arc voltage must increase. This portion of the characteristic corresponds to operation of the filament at saturation. Since a double sheath does not exist in this case, a change in magnetic field strength should affect the characteristic. It was found that an increase in magnetic field resulted in a decrease in the arc drop, which follows directly from the idea of positive ion bombardment.

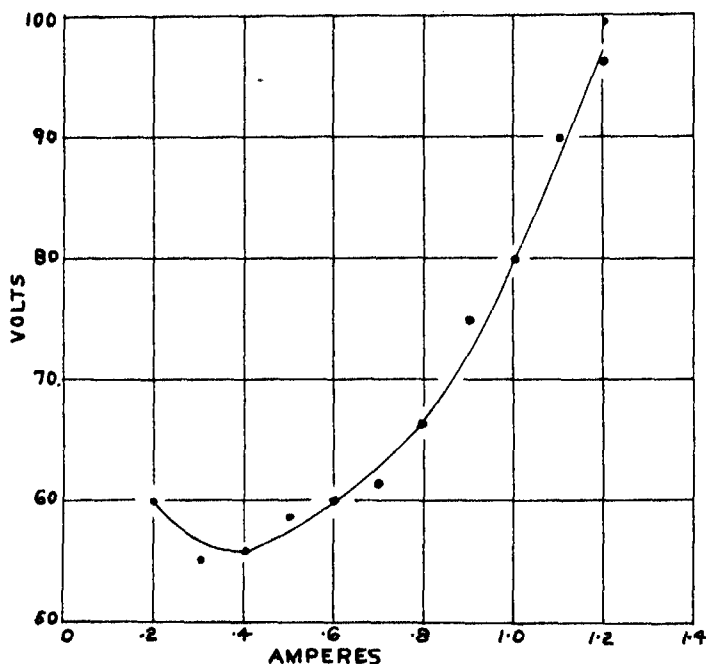


Fig. 3. Volt-ampere characteristic of the arc with tungsten filament at a pressure of 8×10^{-3} mm.Hg and a magnetic field strength of 1000 gauss.

It is believed that the ions collected by the Faraday cage are formed in the capillary itself since the potential gradient in the arc region will prevent ions from leaving that region and entering the capillary. The number of ions formed in the capillary should depend on the number of electrons entering it, and this in turn will depend on the cross-section of the capillary, on the value of the magnetic field strength, and on the value of the arc current. It was found that the ion current collected by the Faraday cage definitely increased with the size of capillary and strength of magnetic field. In making these measurements, a negative potential with respect to the filament was applied to the cage in order to prevent electrons from reaching it. Fig. 4 shows the relationship between cage current and arc current for the case of an oxide coated filament. Similar curves were obtained when tungsten filaments were used. The curves for the oxide coated filament show that the Faraday cage current increases almost linearly with the arc current. The manner in which the grid is connected has little effect on the curves obtained.

In order to obtain some idea of the number of secondary electrons being produced by positive ion bombardment of the Faraday cage, curves of cage voltage against cage current were plotted. Some typical curves are shown in Fig. 5. The shape of the curve was found to be practically independent of all variables except the arc drop. The steeply rising part

of each curve corresponds to the case where electrons are able to reach the cage. The curve flattens out at about 100 volts on the cage, indicating that electrons having energies up to this value are reaching the cage. This voltage corresponds very closely to the arc drop. The portion of the curve for voltages above this value has a slight slope which is believed to be due to the production of secondary electrons by positive ion bombardment of the cage. The proportion of secondary electrons in the Faraday cage current was obtained by measurement of the slope of the curve, and the results agree fairly well with those of Healea and Chaffee.⁴

In order to obtain large ion currents then, one requires a large magnetic field strength, a large capillary, and a large arc current. The

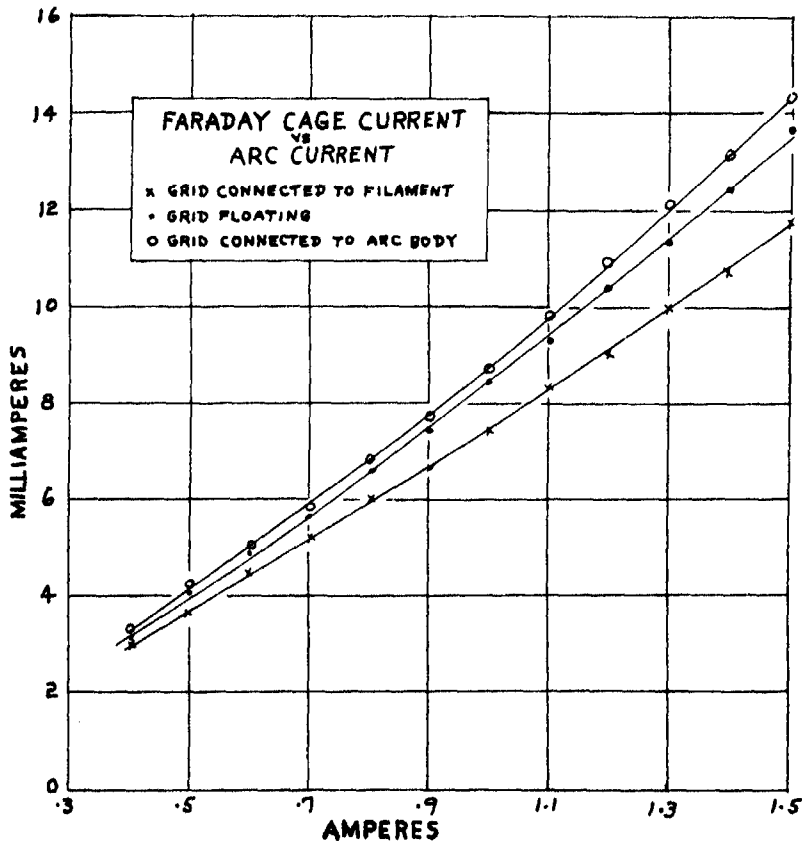


Fig. 4. Dependence of Faraday cage current on arc current for the case of an oxide coated filament. Pressure in the arc region = 2.6×10^{-7} mm.Hg. Magnetic field strength = 1000 gauss. Arc current = 1.5 amperes.

⁴Healea, M., and E. L. Chaffee, 1936. Secondary electron emission from a hot nickel target due to bombardment by hydrogen ions. *Phys. Rev.* 49:925-930.

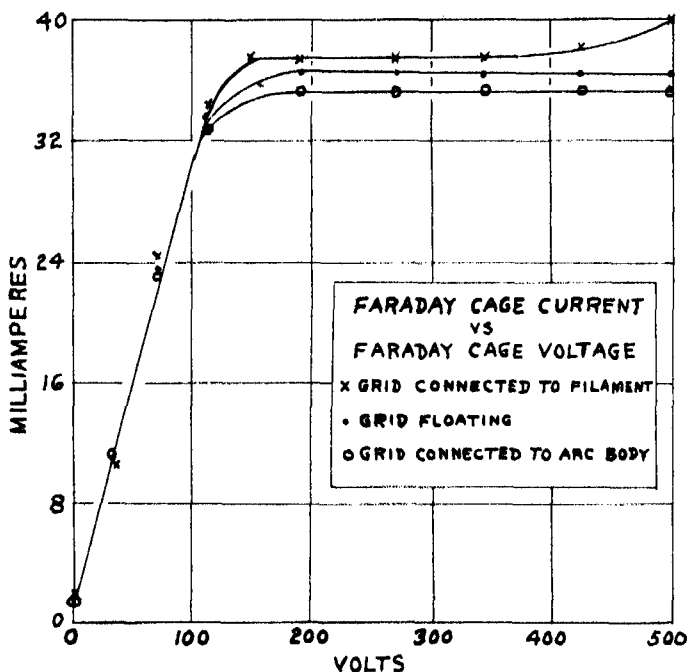


Fig. 5. Dependence of Faraday cage current on Faraday cage voltage for the case of an oxide coated filament. Pressure in the arc region $= 2.9 \times 10^{-3}$ mm.Hg. Magnetic field strength $= 1000$ gauss.

values of these quantities must be chosen to give a reasonable filament life and at the same time satisfy the pressure requirements outside the arc region and give a reasonable rate of gas consumption. With an oxide coated filament, it is quite feasible to use an arc current of 1 ampere, a pressure in the arc region of 3×10^{-3} mm.Hg., a magnetic field strength of 2000 gauss, and a capillary of 200 mils diameter in order to obtain a Faraday cage current of about 25 milliamperes with a reasonable filament life. With a tungsten filament, currents as high as 50 milliamperes have been obtained.

In the near future, this arc will be used as an ion source for the D-D reaction. Following this, an attempt will be made to take the beam out of the magnetic field and analyze it by means of a magnetic spectrograph.

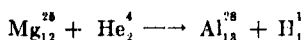
Acknowledgment

It is indeed a pleasure to record our indebtedness to Professor W. J. Henderson, who suggested the problem and gave much valuable assistance.

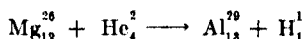
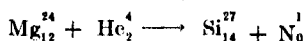
The Alpha Particle Bombardment of Magnesium

R. L. DORAN and W. J. HENDERSON, Purdue University

The artificial radioactivity of magnesium produced by alpha particles was reported in 1934 by the Joliet (1) in their first paper on artificial radioactivity. It was subsequently shown that the main effect is the production of Al^{28} with a half life of 2.35 min. This has been verified from the work with deuterons and neutrons. Magnesium has three stable isotopes and beyond the formation of Al^{28} by



there is the possibility of forming unstable Si^{27} and Al^{30} as follows:



It has been reported that three periods do result from this bombardment (2). They are given as 2.3 min., 7 min., and a period measured as being greater than 11 min. The measurements were made, using alpha particles from naturally radioactive bodies, and, as a consequence, the energy was very much below that available at present. We have used the identical piece of magnesium from which these measurements were made and have bombarded it with the 16 MV alpha particles from the Purdue cyclotron. This stream of particles is equivalent in numbers to

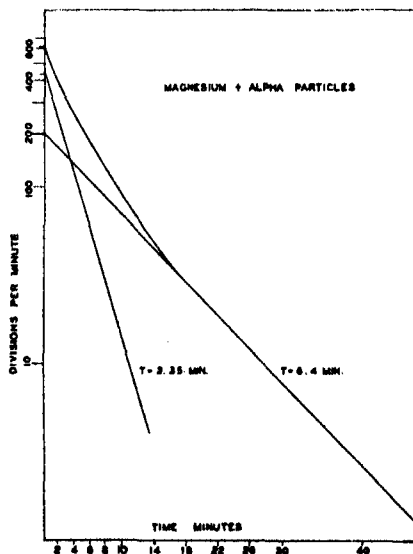


Fig. 1.

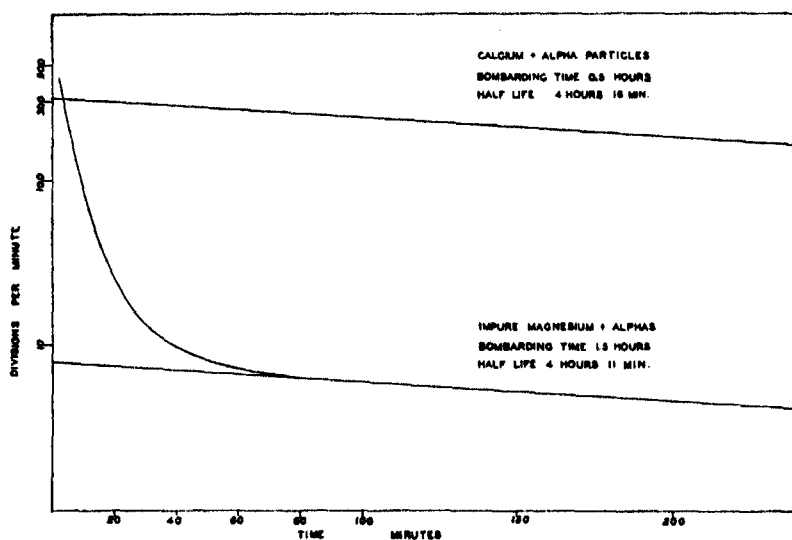


Fig. 2.

that from two or three grams of radium but of very much greater energy. The periods of decay are found to be 2.35 min., 6.4 min., and 4 hr. 11 min.

However, measurements taken from a very pure piece of magnesium supplied by Dow Chemical Company show that under alpha particle bombardment only the periods 2.35 and 6.4 min. are present. Figure 1 shows the decay curve from the pure sample of Mg. The fact that the 4-hour period could not be found suggests that it was due to an impurity in the original sample. Of the likely impurities in Mg, calcium produces

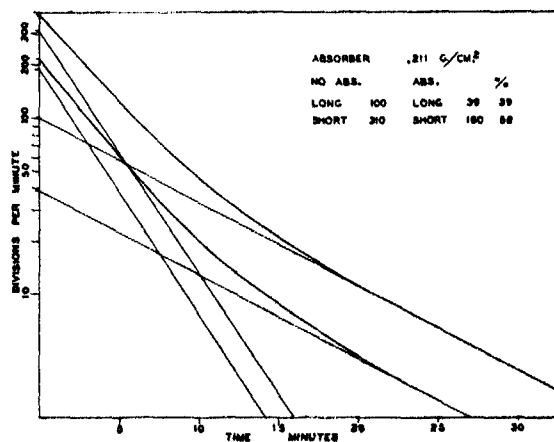


Fig. 3.

this period under the bombardment of alpha particles. Radioactive scandium⁴⁴ is produced in this reaction (3) and decays with a period of 4 hr. 16 min. With a pure calcium target, the 4-hour activity is found to be 300 times greater than in the impure Mg target. An impurity of $\frac{1}{10}$ of 1% of calcium in the magnesium would explain the presence of the 4-hour activity in the original sample. In figure 2 a comparison of the 4-hour activities in pure calcium and the impure Mg is shown.

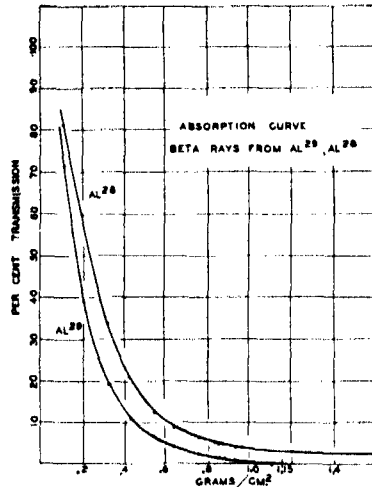


Fig. 4.

Cloud chamber tracks and magnetic analysis show that the emitted particles are beta particles. The decay of Al²⁸ with the emission of beta particles has been definitely shown to have a half-life of 2.35 min. (4). The fact that we do have beta particle emission corresponding to the 6.4-minute decay means that this period is due to the Al²⁸ decay. Just recently it has been shown by proton bombardment of Al that Si²⁸ has a half-life of 3.7 sec. (5). In the present experiment, such a short life-time would not be observed, but there are theoretical reasons to believe that the formation of Si²⁸ will not take place at the present energy of alpha particles.

Absorption measurements were made to determine the upper limit of the beta ray energies, using an electroscope and aluminum absorbers. In plotting this absorption curve, a special technique must be used because we are working with two radioactive bodies whose half-life periods are comparable. Otherwise, one could read the absorption data directly. It was necessary that each point on the absorption curve be made with a new target. For each, target readings were taken alternately with and without the absorber. One curve shows the activity with the absorber in place, and one shows the activity without the absorber. This would eliminate the error due to different bombardment conditions for different sources. The 6.4 min. and 2.35 min. decay lines could be drawn

on the curve and extrapolated to zero recording time, that is, the end of bombardment. Thus, for one particular thickness of absorber, we would know what activity was due to each period with no absorber and also the activity for the absorber in place. The absorption for that point would then be the ratio of the two activities for the 6.4 min. period and a similar ratio for the 2.35 min. period. A sample point is calculated for .211 gm/cm² of absorber in figure 3.

The resulting absorption curves in figure 4 show in the case of Al²⁸ the absorption of the beta rays on a gamma ray background. For Al²⁸ the beta absorption is all that is evident. Apparently, no gamma rays are connected with this reaction, or, if any at all, they are too weak to be detected by this method. The maximum range of the beta particles from Al²⁸ is approximately 1.15 gm/cm². This, according to Feather's Rule (6) corresponds to an energy of 2.4 MV. This value is checked within the limits of experimental error by the mass absorption coefficient of beta rays in Al. This value of 5.35 corresponds to an upper limit of 2.3 MV. From cloud chamber photographs (7) the beta ray spectrum is shown to be continuous and of a maximum value of 2.5 MV. We conclude, therefore, that the maximum energy of the beta rays from Al²⁸ is $2.4 \pm .2$ MV.

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A Simple Method for Obtaining the Solutions of Dirac's Equation for a Free Particle in Spherical Coordinates

J. F. CARLSON, Purdue University

The Dirac wave equation for a free electron.

$$\overrightarrow{(E - c(\alpha \cdot P - \beta mc^2))\Psi = 0} \quad (1)$$

may for convenience be written in the form

$$\overrightarrow{(\epsilon + i\alpha \cdot \nabla - \beta)\Psi = 0} \quad (2)$$

where the units are chosen so that $\frac{h}{2\pi} = \frac{1}{2\pi}$ times Planck's constant; m , the mass of the electron, and c , the velocity of light, are put equal to unity. In these units the unit of length is $\frac{h}{2\pi mc}$, the unit of time is h/mc^2 , and the unit of mass is the electron mass. ϵ is the total energy in these units, $-i\nabla$ the operator representing the momentum, and α and β the four row and column Dirac spin matrices.

Let us call the operator $\epsilon + i\alpha \cdot \nabla - \beta = H$ and define the operator

$K = \epsilon - i\alpha \cdot \nabla + \beta$. Consider the product HK . By using the well-known properties of the α 's and β , namely,

$$\begin{aligned} \alpha_x \alpha_y + \alpha_y \alpha_x &= 0, \text{ etc.} \\ \alpha_x \beta + \beta \alpha_x &= 0, \text{ etc.} \\ \alpha_x^2 = \alpha_y^2 = \alpha_z^2 = \beta^2 &= 1 \end{aligned} \quad (3)$$

we find for the product of H and K that

$$HK = \nabla^2 + \epsilon^2 - 1 \quad (4)$$

where ∇^2 is the Laplacian. Defining $\epsilon^2 - 1 = k^2$, we have $HK = \nabla^2 + k^2$. Now consider the partial differential equation

$$(\nabla^2 + k^2)\Phi = 0 \quad (5)$$

and let us express ∇^2 in spherical polar coordinates. The solutions Φ of this equation are well-known.

$$\Phi = \frac{R(r)}{r^{1/2}} S(\vartheta, \phi) \quad (6)$$

where $R(r)$ is a Bessel function and $S(\vartheta, \phi)$ is a spherical harmonic. Now let us return to our original equation, $H\Psi = 0$ (2).

If we put $\Psi = K\Phi$ we obtain the differential equations $HK\Phi = 0$ (7) so that $\Psi = K\Phi$ is a solution of the Dirac equation for a free particle in spherical polar coordinates. Since the operator K is a matrix, each column of the matrix gives us the four components of the solution.

The four columns, then, are the four independent solutions corresponding to the two independent orientations of the spin and to the two possible values of the energy associated with a given value of the momentum.

PSYCHOLOGY

Chairman: AMMON SWOPE, Purdue University

The section on psychology was well attended, and most of the papers read were followed by general discussion. Some of the papers had marked vocational or industrial implications.

R. A. Acher, of Indiana State Teachers College, was elected chairman of the section for 1940.

ABSTRACTS

The civil aeronautics authority flight training program—psychological problems. AMMON SWOPE, Purdue University.—Preliminary to the investigation, letters were sent to 30 schools engaged in training pilots for aviation service. Reports of these institutions showed that no consistent scheme of selecting pilots was followed. Some of the common forms of selection placed emphasis on mathematics, physics, English, or high school graduation. In many cases high school graduation is not required. After a critical study of various articles, it was found that psychological problems could be organized under such headings as acceleration, altitude, aptitude, occupations, orientation, sickness, and vision. It is impossible to give any single conclusion to the series as here presented, but many of the findings in our laboratories might be adapted to the selection of pilots.

An experimental study of changing patterns of response during conditioning of dogs. IRVIN S. WOLF, Indiana University.—Six mongrel dogs were trained by the buzz-shock technique with shock delivered only to the right rear limb. Simultaneous recordings were made of the movements of all four limbs and of breathing throughout a training series involving 400 stimulations. Conditioned behavior was found to be diffuse and qualitatively different responses were observed for the various animals and for the same animal at different stages of training. Abrupt changes in systematic behavior resembling Krechevsky's "hypothesis behavior" were indicated. Curves describing both the acquisition of the right rear limb flexion and the elimination of less adaptive behavior in other members suggest both the usual increasing conditioning curve and the decreasing trial-and-error curve for conditioned behavior recorded simultaneously. Two general methods of development of the adaptive response were found. Some animals gradually built up the coordination between the right foot response and the conditioned stimulus. Others developed conditioned struggle and later eliminated the responses in the non-shocked members.

A study of teachers' and pupils' attitudes. HARRY MASON, Purdue University.—Social attitudes of over 900 pupils in social studies courses in Arsenal Technical High School in Indianapolis, as well as those of

their teachers, were measured at the beginning and end of a semester's work. Relationships found between attitudes and factors concerning the school and out-of-school environments of pupils were studied for their possible significance to the teaching of the social subjects as well as for their theoretical interest.

Some recent applications of psychology in industry. JOSEPH TIFFIN, Purdue University.—This paper is a summary of recent research in industrial psychology concerning selection tests, job analysis by psychological tests, and possibilities for training. The validation of selection tests for assembly work and inspection work in specific plants is evaluated with a description of the tests finally adopted by a number of representative industries for use in actual employment. Possibilities of job analysis by test is illustrated by means of specific experimental results from the steel industries. These results show how employees may be measured by means of testing situations which determine their efficiency on various aspects of the job. The use of the above results in a training program designed to develop efficiency in new employees in the most economical manner is presented.

The effect of physical performance on the eyes. LYLE TUSSING, Purdue University.—The study shows the effect of fatigue on various eye functions. Male subjects were used. Fatigue had been administered in several different ways. Changes in fatigue are subjectively recorded on a seven-point scale. The eye tests were given before and after submitting the subject to the fatigue situation. The eyes are affected by fatigue even though the fatigue is of such nature as not to call for eye strain of itself.

A preliminary study of information in the field of home economics education held by students in entering the home economics departments of colleges in Indiana. ALMA LONG, Purdue University.—This is part of an extended program planned for the study of curriculum materials and some results of teaching in the field of home economics education at the high school level. The results of a test which was given to students entering the home economics departments of colleges in Indiana have been analyzed to test the usefulness of such an instrument in determining the kind and extent of specific information acquired previous to college entrance, to suggest the relationship such bodies of knowledge may have to the curriculum in home economics offered at the high school and first year college levels, and to suggest areas in which further research might be needed. Questions were raised also concerning college training which takes into account differences in the proficiency of students and the high school and college teaching which produces maximal individual development.

The relationship between marital compatibility and personality traits of husbands and wives as rated by self and spouse. E. LOWELL KELLY, Purdue University.—Seventy-six husbands and their wives were each asked to compare themselves on 36 personality traits. For example, a husband was asked to rate both himself and his wife on such traits as honesty, cooperativeness, sincerity, punctuality, and initiative; she was

asked to rate both herself and her husband on the same traits. All returns were anonymous. Each husband and wife also filled out a set of questions which were scored to yield a measure of the degree of marital happiness achieved by the couple. In general, happily married husbands and wives tend to rate their own personalities above average but rate their spouses even higher. Conversely, couples with low compatibility scores tend to think less well of themselves and rate themselves as superior to their spouses.

The readmitted student. M. L. FISHER, Purdue University.—Every year a considerable number of students are dropped from University rolls by reason of poor scholastic performance. Studies were made of the students dropped during scholastic years and summer sessions of 1931-32, 32-33, 33-34, 34-35, 35-36, involving a few over 1,100 students. Data were tabulated and analyzed. In round numbers 22% of those dropped and readmitted were later graduated and 7.5% were still in school in Purdue University. No information is given concerning those who may have gone to other institutions and graduated.

ZOOLOGY

Chairman: C. P. HICKMAN, DePauw University

About 75 persons were present during all or a part of the session of the section on zoology. Sixteen papers were presented. An outstanding one of these, as indicated by interest and discussion, was that by W. A. Hiestand, Helen J. Ramsey, and Doris M. Hale on the physiological effects of cigarette smoking.

W. A. Hiestand, Purdue University, was elected chairman of the section for 1940.

ABSTRACTS

The effects of cigarette smoking on metabolic rate, heart rate, oxygen pulse, and breathing rate. W. A. HIESTAND, HELEN J. RAMSEY, and DORIS M. HALE, Purdue University.—To determine the effects of smoking on various functions, 39 subjects of both sexes, some confirmed smokers and some light smokers, were used in a non-basal metabolic state. A half-hour rest period was allowed before the test, but no precautions were taken to secure post-absorptive repose. A second series was undertaken with 20 habitual smokers in a basal condition of post-absorptive repose. Determinations were made for each individual at 15-minute periods following smoking to determine the durability of the effects. The non-basal subjects showed considerable individual variability, marked increases and decreases being noted in each function. The average increase in metabolic rate was 7.7% in men and 9.9% in women; the average increase in heart rate was 5.9% in men and 6.4% in women. In the basal subjects the metabolic rate rose 14.3% immediately after smoking, then fell slightly and rose again; the duration of the effect beyond 45 minutes after smoking was not determined. The heart rate rose 16.7% immediately after smoking, quickly fell to slightly above normal, and was 2.6% below normal at the end of the experiment. The oxygen pulse first dropped to 2.1% below normal and then continued to rise, reaching 11% at the end of the experiment. The breathing rate first fell to 7.4% below normal and then rose to 1.1% below normal at the end of the period. The behavior of the oxygen pulse indicates an immediate decrease in the adaptability of the heart with a gradual recovery.

The life cycle of *Monorcheides cumingiae* (Martin) (Monorchiidae, Trematoda). W. E. MARTIN, DePauw University.—The life cycle of *Monorcheides cumingiae* involves the development of the larval stages in the marine clam, *Cumingia tellinoides*, and the maturation experimentally in the flounder and eel. The anatomy, effect on the clam, and the ecological relationships of the parasite are considered.

A note on the occurrence of a syrphid larva as an accidental parasite of man. HELEN L. WARD, Purdue University.—A parasite from the intestine of a woman from Oaktown, Indiana, has been identified as the larva of a syrphid fly, possibly *Eristalis tenax* (Linn). The single speci-

men was sent to Dr. H. E. Enders by Prof. Beghtel of Evansville College and referred to the writer for study. The larvae of syrphid flies have been reported from time to time as human parasites. Their presence in the intestine is due to accidental ingestion of the eggs or larvae in water or food. The symptoms which have been described are nervousness, indigestion, headache, and emaciation.

Panting and temperature regulation in the chicken. W. C. RANDALL and W. A. HIESTAND, Purdue University.—Panting in the chicken as a response to rising body temperature was demonstrated in this investigation. That panting is regulated by a center separate from the respiratory center is indicated by the use of centrally acting drugs. Reflex inhibition of panting following external chilling invariably occurred even though no appreciable drop in internal temperature was noted. Above a certain upper critical temperature level the panting mechanism begins to fail, resulting in a reduced rate. Central depression reduces panting rate, and deep anesthesia abolishes it entirely, light anesthesia raising the panting temperature. Depressant drugs affect the panting center independently of the respiratory center. Central stimulation (lobeline) results in increased panting and respiratory movements followed by a longer period of increased sensitization of the panting mechanism. This sensitization is apparent in a lowered panting threshold, an increase in panting rate in relation to internal temperature, and a greater maximal panting rate.

Egg production in trematodes with special reference to *Spelotrema nicolli* (Microphallidae). R. M. CABLE, Purdue University.—In studying the life history of *Spelotrema nicolli*, egg formation has been observed repeatedly. The oocyte, separating gradually from the ovarian mass while the preceding egg is formed, is propelled down the oviduct and passes into the ovijector which contracts instantly, forcibly expelling the oocyte into the ootype. This produces an enlargement of the beginning of the ootype where currents produced by long cilia rotate the oocyte rapidly for a few moments, facilitating fertilization. The zygote, forced along the ootype by a series of contractions until it reaches the opening of the vitelline reservoir, pauses there and is provided with a mass of vitelline material which is squeezed into the ootype by a series of contractions of the vitelline reservoir. Excess vitelline material and occasional sperms are voided through Laurer's Canal. The zygote surrounded by this material then passes just beyond the openings of the shell gland into the egg chamber, the muscular walls of which mold the egg as the shell material hardens. The egg is kept in constant motion by contractions of the egg chamber and may be turned end for end several times before the shell is completed. A much stronger contraction now begins back of the finished egg and ejects it into the uterus; at the same moment another oocyte moves down the oviduct, and the process is repeated. In one instance, it was noted that 24 minutes elapsed between the descent of one oocyte and that of the succeeding one. At the relatively high body temperature of the host, however, egg formation must proceed much more rapidly than

observed at room temperature, as indicated by the number of eggs present in young worms.

Notes on *Miranda aurantia*. FRANCIS WENNINGER, University of Notre Dame.—*Miranda aurantia* is the name that should be used although at least 28 writers mention neither the genus nor the species. The peculiar position of the eyes, some prominences, and other internal features, mating and egg-laying, and the disposition of the nest are noted.

Preliminary limnological survey of Dewart Lake, Kosciusko County, Indiana. MURVEL R. GARNER, MARKLAND MORRIS, and GLEN WOOD, Earlham College.—A preliminary limnological survey of Dewart Lake was made during the summer of 1939 with a view to making a continuous comparative study through a period of years. The usual limnological data with respect to physical, chemical, and biotic determinations were taken. The lake, which lies between Tippecanoe and Wawasee, is a relatively small one and has large areas of shallow water. The significance of the ratio of shallow water and deep water is being studied from the standpoint of biotic productivity in order to make comparisons with some of the nearby larger lakes. The significance of an artificial raising of the level of the lake many years ago by a low dam is also under study. Preliminary reports on data obtained are tabulated.

Insects of Indiana for 1939. J. J. DAVIS, Purdue University.—This paper is a discussion of the major insect problems in Indiana during the past year, with explanation of causes of insect abundance or scarcity, and new developments in insect control.

Records of Indiana dragonflies, X. 1937-1939. B. ELWOOD MONTGOMERY, Purdue University.—New county, seasonal, and other records of Odonata, based upon collections of 266 specimens (29 species), 414 specimens (49 species), and 1455 specimens (54 species) made in Indiana in 1937, 1938, and 1939, respectively, are listed. Observations showing the establishment of *Celithemis fasciata* Kirby, a southern species, at a lake near Oakland City, are noted. Ecological notes and discussions of variations observed in certain species are given.

Recent Experimental Work on the Mammalian Adrenal Cortex

C. P. HICKMAN, DePauw University, and R. R. OVERMAN,
Harvard University

For some time the authors of this paper have been investigating the effects on the mitochondria and other structures of the adrenal cortex in white mice when Collip's adrenotropic hormone is injected into them under control conditions. In connection with certain aspects of this work, and as a background for it, we are presenting this review of some of the recent experimental modifications of the mammalian adrenal cortex. In this account we wish to emphasize the general histological structure of the cortex and the prevailing views regarding its formation. Without a doubt much of the knowledge about the adrenal gland has been derived from the study of its physiological cytology. The very fact that the adrenals have had so many functions assigned to them in recent years implies great complexity in their physiological action. Although there seems to be a certain amount of uniformity in their structure among various mammals, it is not possible in our present state of knowledge to homologize all their details. There is considerable diversity in the histological components of the adrenal cortex, and it may be that such diversity of structures is associated somewhat with functional differences.

As a general thing, the functions of the adrenal cortex are even more shrouded in mystery than are some of the other endocrine glands. A list of symptoms displayed by adrenalectomized animals will give some idea of the ramifications of the action of the cortex. In recent years, it has been shown that animals without adrenals and without any type of replacement therapy show sodium excretion above normal, marked dehydration, rise in blood urea, retention of potassium in the blood, loss of glycogen storage, decrease in blood glucose, hypotension, pigmentation of the skin, susceptibility to toxins, gonadal disorders, lactation disturbances, and several other effects. In view of such varied functions, it seems easier and more to the point to enumerate the things this much-functioning gland does not do.

General histological structure of the mammalian adrenal cortex.—

It is well known, of course, that the adrenal glands in mammals consist both structurally and functionally of two distinct separate parts, the cortex and the medulla. Each of these parts, it is also well known, has its own separate and distinct origin. The comparative anatomy of the two regions, as traced through the different vertebrate groups, is a very interesting one.

As a general feature, the adrenal cortex is formed of cords of cells, between which lie reticular tissue and capillaries. These cords are generally two cells wide. Since the shape and arrangement of these cords differ throughout their course, the cortex has been divided in a somewhat arbitrary manner into three zones: an outer or *zona glomeru-*

losa, a middle or *zona fasciculata*, and an inner or *zona reticularis*. As we shall point out later, we should not adhere to this zone division rigidly. It simply represents a convenient way of understanding the main features of the cortex.

There is considerable variation in cell types in the cortex among the different layers. In the *zona glomerulosa*, which is the narrowest of the three, the cells are columnar or sometimes pyramidal, arranged in ovoid groups or in small arcs which cap the next layer, the *zona fasciculata*. The nuclei of these cells stain deeply. Lipoid droplets are few in number.

The *zona fasciculata*, which makes up the widest part of the gland, as a usual thing, consists of larger cells chiefly polyhedral in shape. In the outer fasciculata region the cells stain rather lightly, and there are numerous lipoid droplets which, when dissolved away, give this region a spongy appearance. There are often two or more nuclei in each cell. In the inner part of the fasciculata the cells diminish in size and contain basophilic granules which stain deeply with iron hematoxylin. The cells of this region are arranged in cords.

The innermost zone, the *zona reticularis*, has its cells arranged in anastomosing cords. The outer cells of this region are similar to those in the fasciculata zone, except that they have fewer lipoid droplets. In other parts of the zone there are two distinct kinds of cells, light and dark. The light cells are more numerous than the dark ones and have rounded contours. The dark cells are smaller with a deeply staining cytoplasm and small shrunken (pyknotic) and hyperchromatic nuclei. Light cells have fewer mitochondria and lipoid droplets than the dark cells. The difference between the two kinds of cells seems to be a matter of difference in lipoid emulsification. Light cells have their protein material scattered among small lipoid droplets; dark cells have larger lipoid droplets, and the protein part, which stains darkly, here shows up to a better advantage. There are many transitional forms between the light and dark cells. There is also much cellular debris in the reticularis zone. The light and dark cells probably represent stages of degenerating, senescent cells.

According to most authorities who have studied the problem, there is a growth from without inward in the cortex, and there is a corresponding continuity of cell types. It is the belief of most that there is a normal progression of the cell from the spindle, fibroblast-like cell of the capsule through the ovoid or prismoid shapes of *zona glomerulosa* and *zona fasciculata* to the small heterogeneous, hyperchromatic cells of the reticularis zone. In the reticular region the presence of cellular debris would tend to show a breakdown of old cells whose function and shape have changed through the zonal progression from capsule to medulla. Most workers agree with Hoerr ('31) that the different functions of the cell types are independently derived or else are the different functional states of the same cell.

Most cases of mitosis are found in the fasciculata zone or in the border between the glomerulosa and the fasciculata. Usually only a few are found in the reticularis layer, and these are chiefly in young animals.

The adrenal X zone.—In some mammals, especially in mice, and possibly to some extent in the cat, rat, human, and a few other species, a so-called X zone has been described by many writers. This zone has often been included in the *zona reticularis* by most observers, but others regard it as a separate zone, although a transient one. It is not present in the adrenal of the adult male mouse although it first appears in both sexes at about three weeks of age. The cells of this zone are characterized by being small and free from lipoid droplets and staining darkly. In mice which are early castrated (before five days of age) the zone may develop to the extent of one-third or more of the entire cortex. In the female the X zone is normally larger and persists for a longer time, disappearing in that sex in the middle of the first pregnancy or later in the non-pregnant female. In the female its growth and development are unaffected by ovariectomy.

In mice castrated after sexual maturity, when the primary X zone has disappeared, a secondary X zone appears but disappears about 100 days later. It is thus seen that the spontaneous manifestation of the X zone is restricted to a limited portion of the life cycle. It has also been shown that castration changes in the mouse can be inhibited by injections of male hormones. Howard ('39) recently found that there is a correlation between the development of the seminal vesicles and that of the X zone. These and other experiments have given rise to the belief that gonadal hormones are produced in regions outside of the reproductive system, but in the course of development this function becomes concentrated in the gonad. However, in dwarf mice X zones fail to develop after castration. This may mean that the pituitary may also be involved in some way.

In rats, Howard ('38) has shown the presence of a zone, similar in most ways to the X zone of mice, which she calls the juvenile cortex. This zone appears well developed in rats of both sexes at three weeks of age and has almost disappeared in 40 days. This juvenile cortex shows no age differences and is little influenced by castration. The juvenile cortex is, for the most part, transformed into the adult reticular zone although some of its cells tend to persist in an isolated condition.

Man shares with mice in having the most X zone development, but in this case the zone degenerates soon after birth.

In the rabbit there are actually four zones in the adrenal cortex. The innermost interlocks with the medulla, but it is not known whether this inner zone may or may not be homologous with the X zone of the mouse.

Cytoplasmic inclusions of the different zones of the adrenal cortex.—Many investigators have described the mitochondria of the mammalian adrenal cortex, and, as a general thing, there is agreement among them regarding the shape and arrangement of these cytoplasmic inclusions. In the *zona glomerulosa*, where they are unusually abundant, the mitochondria are found chiefly in the form of threads and short rods; in rarer cases, they are in the form of granules. In some cases, these threads have beaded or clubbed ends. In the *zona fasciculata* they are found in the form of granules and are placed in the spaces between the

lipoid inclusions. In the *zona reticularis* most of the mitochondria are in the form of rodlets which often clump together in a characteristic fashion. Although some writers have reported that the mitochondria are less abundant in this zone than in the others, this view has probably arisen from poor fixation. Nearly all workers agree that the *zona reticularis* is the most difficult part of the cortex to fix. Whenever good fixation is employed, the *reticularis* will show as many of the inclusions as the other zones. However, it should be pointed out that there is considerable variation in the distribution of mitochondria in the cortex of various mammals. In some cases, there is a marked tendency for them to be accumulated in clusters near the nucleus; in others they are scattered throughout the cytoplasm. Such differences cannot always be made accountable on the basis of differences in technique. The fact that mitochondria are more abundant in cells where there is little lipid proves nothing, for they may here show up to greater advantage.

In the adrenal cortex the Golgi apparatus appears chiefly in the form of a network of filaments with varicosities. Around this network there are often small spheres. There is also a fairly close relationship between the Golgi apparatus and the cell vacuoles.

Lipoid inclusions of the different zones.—Lipoid inclusions of some form are found in all the cortex zones. They are especially abundant in the *fasciculata* cells, and, when the lipid is dissolved out, the cells present a peculiar vacuolated cytoplasm. From this appearance the cells here are called spongiocytes. The *zona reticularis* contains much less lipid, and the light cells found in some contain little or none. Zalesky ('36) distinguishes two varieties of liposomes in the cortex of the guinea pig. The smaller ones, which he calls microliposomes, are 0.4 to 2.5 microns in diameter. The larger are known as macroliposomes and are from 3.5 to 20 microns in diameter. The macroliposomes may be intercellular although usually they are intracellular. They do not stain as deeply with osmic acid as do the microliposomes and are often dissolved out completely with alcoholic dehydration and infiltration with paraffin. A chemical difference between the two is evident. The macroliposomes are confined chiefly to the *fasciculata* zone; the microliposomes have a much wider distribution.

Experimental modifications of the histological structure of the adrenal cortex.—Investigations on the experimental modifications of the mammalian adrenal cortex have been numerous in recent years. Naturally, most of this investigation has centered upon the gland with the purpose of determining its varied functions. The problem of the exact role of the adrenal cortex has been attacked from many angles. In the space of this paper it is impossible to report on all of this investigation. We wish to point out some of the most striking work recently performed on the adrenal cortex and to indicate the main conclusions to be drawn from this work. In spite of contradictory points here and there, there is much of a definite character that seems to be well established.

The experimental modifications of the cortex has mainly involved two methods: (1) the effects produced in the cortex by the removal of

other endocrine glands and (2) the effects produced by the injection of substances such as hormones and toxins as well as other things.

Considering the interrelations of the endocrine glands, it is quite logical that much of our knowledge of the adrenal cortex has arisen from the removal of other glands, or glandectomy, noting the effects of the removal. Hypophysectomy has been one of the most common. There is almost general agreement that such operations lead to marked atrophy of the adrenal cortex. Reese and Moon ('38) have shown that many changes in the cortex begin a few hours after this operation. This is especially the case with the Golgi apparatus which remains in a shrunken form for 300 to 400 days after hypophysectomy. Cutuly ('36), working on the same animals, rats, observed that the greatest atrophy occurred 30 days after the operation. Crooke and Gilmour ('38) observed in immature rats that this degeneration is most evident in the reticular zone where the cells were reduced in number and there was a marked infiltration of lymphocytes as well as an increased pigmentation. The lipid content in the same zone was also reduced.

Simmons and Whitehead ('37) reveal that in cases of unilateral adrenalectomy the cortex of the unmolested adrenal shows a decrease in the fat density in the outer zone of the gland but an increase in the inner part. As regards gonadectomy and its effects on the cortex, Zalesky ('36) found that the operation performed before sexual maturity induces no permanent hypertrophy or atrophy in the guinea pig adrenal but does cause some increase in the lipoids of the cortex.

It has long been known that animals dying from adrenal deficiency show symptoms similar to those in severe toxemia. Moreover, animals which survive double adrenalectomy are more susceptible to various toxins than are the normal controls. Deanesly ('31) found that the injection of certain bacilli, morphine, and other toxins appears to have the same effect on the cortical zones as that of thyroxin. These changes are associated with enlargement of the cortex and a considerable decrease in the cortical fats and lipoids. Schmidt and Schmidt ('37) discovered that ingestion of thyroxin resulted in an increase of mitotic activity, but in this case the scene of the mitoses was confined chiefly to the *zona fasciculata* instead of being also in the *zona glomerulosa* as was the case with control animals.

A marked atrophy of the cortex is produced when large amounts of cortin are administered to an animal. Ingle ('38) points out that, when this is injected into a normal animal, the adrenal cortex decreases. If the hypophysis has been removed, however, and the animal receives the adrenotropic hormone, there is no apparent effect of cortin on the adrenal cortex. Reese and Moon ('38) state that the injection of the adrenotropic hormone causes hypertrophy of the Golgi apparatus in the cortex of the normal male rat. When this hormone is injected into the hypophysectomized animal, however, the hormone not only maintains the normal appearance of the apparatus but also causes it to hypertrophy. Many other investigators confirm this.

In many of these experimental modifications one thing is quite noticeable. Of the three zones, the cells of the reticularis are unusually sensitive to diseases and toxins. This may be due to the fact that these

cells are senescent or dying and receive an enormous blood supply which brings them into contact with a large quantity of the noxious agencies.

A preliminary account of the authors' work on the adrenal cortex of the albino mouse.—Our own work has centered mainly upon one or two aspects of the physiological cytology of the adrenal cortex, especially upon cytoplasmic organelles. The theory has long been known in biology that there is a relation between certain cytoplasmic inclusions and the functions of the cell. Most of the attention in this respect has been directed to the organs of exocrine secretion where it has been possible to stimulate them to their optimum rate. In this way it is possible to follow the cells in their secretory cycles.

Only recently have the organs of endocrine secretions been so studied since little has been known of their secretory rate, their intrinsic secretory cycle, methods of bringing about optimum secretory activity, and their secretory products. But with the recent purification and the fairly accurate assay of endocrine material, the authors are endeavoring to repeat, using the adrenal cortex, the work of earlier exocrine cytologists.

The mouse adrenal was chosen as the optimum tissue, owing to its small size and the ease of its fixation in the entire condition. Cell structures are very sensitive to manipulation, and fixation of the much larger adrenals of the common laboratory animals is not feasible for most of this cytological work.

Experimental animals (adult albino mice) were given one Collip rat unit of the adrenotropic factor. The substance used for this was Ayerst and McKenna's growth complex, which contains growth substance as well as the adrenotropic factor. Since adult animals were used throughout, the growth factor can be ruled out as affecting our results. Controls were given a similar volume of standard saline solution.

Our results, to date, show, among other things, that the adrenal weights of the mouse bear no absolute constant relation to the body weight but may vary in the normal animal from 0.01% to 0.035% of the body weight. In all cases of experimental animals, the weights increased up to more than 0.06% by the fifth day following administration of the hormone. The average actual weight of adrenal material in the normal mouse is 5 mg. Actual weights increased in some cases as much as three times the normal by the fifth day after injection and in all cases had at least doubled by that time.

Gross histological examination reveals that the cortex had increased greatly in width in relation to the width of the entire gland. The increase seems to be confined mainly to the *zona reticularis* and *zona fasciculata*.¹

Weight increases seem to be due to this augmented activity as well as to the appearance of more lipoids in the gland.

The glands were fixed according to the formalin-bichromate and other techniques, and observations to date reveal that there is an in-

¹Work on this point, using colchicine to determine the mitotic index of these regions, is being done at the Biological Laboratories, Harvard University, by the junior author.

crease in mitochondria in the reticularis and fasciculata zones, that there is an increase in the rod-like forms of mitochondria, that the granular forms appear to be swelled, and that the mitochondria is seen for the most part on the capillary side of the cell.

Further work to extend these preliminary findings is under way.

Conclusion.—At the present time we may briefly conclude that the mammalian adrenal cortex is a gland of continuous change as regards its histological and cytological make-up. It may be considered a complex of cells, which in their migration from capsule to medulla undergo a progressive change of cell types more or less localized into different zones. These cell types reveal differences in cytological details, as lipoids, cell inclusions of various kinds, size relations, etc., which are correlated with the stages in the life history of the cell. Moreover, the experimental modifications induced by such agencies as injections of toxins, and hormones, and by glandectomy are manifested chiefly in an accelerated or retarded differentiation of these cell relations and characters. But the picture is far from complete, and there are yet lacking many details which must be filled in before we can arrive at a sound morphological and functional interpretation of the adrenal cortex.

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A Table for the Normal Development of *Rana pipiens*¹

DOROTHY C. MILLER, Indiana University

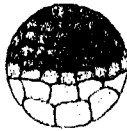
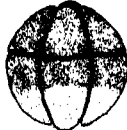
In 1918 Harrison prepared a series of arbitrary stages in the normal development of *Amblystoma punctatum* which has never been completely published. Drawings of some of the stages have been included in his papers and those of his students, who frequently refer to the series. In fact, in the later papers the drawings are no longer included since the stages have become well known. There are at least forty-six stages in this series, but there is no attempt to correlate the age of the embryo and the stage and no reference to the temperature at which development took place. In 1937 Pollister and Moore published a chart for the normal development of the frog, *Rana sylvatica*. This chart differs from the *Amblystoma* series by having only 23 stages which are correlated with age, temperature of development, and size in the older stages. These stages are also arbitrary but mark rather easily determined steps in development.

The usefulness of such a series or chart is shown by the frequent reference to the one of *Amblystoma*. The value of similar charts for anurans used in experimental embryology is threefold. First, the charts would place in the literature standard series of developmental stages for reference. Second, they would simplify the description of experimental results since it would no longer be necessary to include detailed diagrams and descriptions of the stages used. Third, they would reduce the necessity for large control groups since the normal stages are already known. This paper presents such a chart for the normal development of *Rana pipiens*.

Rana pipiens lays in the vicinity of Bloomington, Indiana, from about March 1 until April 15. Most of the eggs used for this study were collected from ponds around Bloomington, brought into the laboratory, and placed in a dark room with a constant temperature of 15° C. The earliest stages were secured from eggs laid in the laboratory and supplied to me from other experiments. These eggs were placed under the same conditions as those collected from the ponds and showed no differences in development.

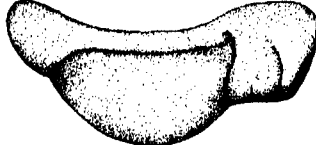
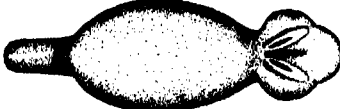
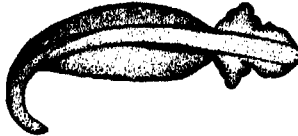
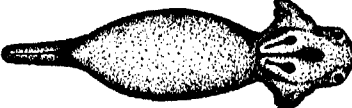
These eggs for the earliest stages were secured by pituitary injection of the adults, using the method of Rugh ('34). Rugh found that ovulation can be induced in *Rana pipiens* at any season of the year by the injection into the body cavity of whole or macerated frog pituitaries. He found that the most effective method was to inject two female pituitaries daily. This resulted in ovulation on the second to fourth day. If fertilization was desired, amplexus could be induced by pituitary injection of both the male and female, or the eggs could be stripped from the uterus into a sperm suspension prepared from macerated testes.

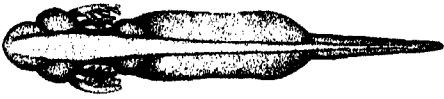
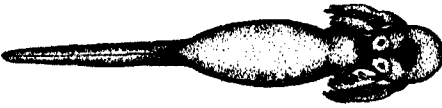
¹This paper is based on a thesis submitted in partial fulfillment of the requirements for the A. M. degree in zoology. Contribution No. 288.

ST. NO.	AGE HRS. /5°C	EXTERNAL FORM	ST. NO.	AGE HRS. /5°C	EXTERNAL FORM	ST. NO.	AGE HRS. /5°C	EXTERNAL FORM
1	0		6	75		11	34	
2	1+		7	10		12	44	
3	3		8	16		13	54	
4	45		9	20		14	57	
5	6		10	27		15	65	

Every two hours, after the 16-celled stage, the developing eggs were studied and sketched from the live specimens. At the same time 20 to 40 eggs were fixed in Tellyesnick's fluid and preserved in 5% formalin. These preserved eggs verified the sketches and formed the basis for the drawings of the stages selected. In each case the drawings are of individuals average in size and extent of development for the group. The stages figured and described correspond as exactly as possible to the ones figured and described by Pollister and Moore for *Rana*

sylvatica. This has been done for two reasons: to prevent a confusion of stages in the literature and to make a comparison of the species possible. The stages are designated by the external morphology and the age in hours after laying. For the earlier stages the number of cells, relative size of the cells, or development of the neural tube forms an adequate basis for determination. For the later stages, however, several factors, such as the transparency of the cornea and epidermis, elongation of the body, growth of the external gills, and coiling of the gut are helpful in determining the stage designated. Certain physio-

ST. NO.	AGE HRS. 15°C	EXTERNAL FORM	ST. NO.	AGE HRS. 15°C	Length mm	EXTERNAL FORM
1677		 	189235			  
1781		 	191025			  

ST. NO.	AGE HRS. 15°C	Length mm.	EXTERNAL FORM	
20126	7			
				
				
			HATCHING	SWIMMING
21151	8			
				
				
			CORNEA TRANSPARENT	

logical features of development, such as the beginning of muscular movement and of swimming and spontaneous hatching, have been used as stage markers.

Description of Stages of *Rana pipiens*

In the following, the numbers refer to figures 1 to 28.

1. The unfertilized egg.
2. Gray crescent formed.

3-6. Early cleavage stages.

7-9. Stages in cell multiplication. The relative size of the animal and the vegetal hemisphere cells form the best criterion for determination of these stages.

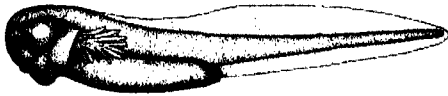
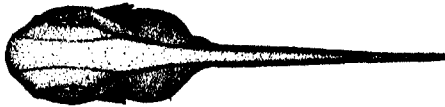
10. Appearance of the dorsal lip of the blastopore.

11. Blastopore almost semi-circular.

12. Blastopore complete, the late yolk plug stage.

13. Neural plate stage.

14. Neural folds formed.

ST. NO.	AGE HRS. 15°C	Length mm.	EXTERNAL FORM	
22	180	9.5		
				
				
23	205	12		
				
				
			TADPOLE FORM	OPERCULUM CLOSING

15. Beginning of the closure of the neural tube, also the beginning of the elongation of the embryo.

16. Neural tube completely closed.

17. Beginning of the tail bud. When this stage is viewed laterally, the tail is seen marked off by a notch.

18. Capable of simple lateral movement when stimulated. There is also an indication of the division to form the gills. First distinct curvature of the body.

19. Tail equals one-third of the body length, the division of the gills is becoming definite. The embryo can be hatched by vigorous shaking.

20. Spontaneous hatching occurs in this stage, capable of simple swimming movements when disturbed. The gills are well formed. Tail equals one-half the body length. Epidermis along edges of tail becoming transparent.

21. The cornea is becoming transparent. The fold of the operculum is beginning to form. Tail almost the length of the body.

22. Trunk asymmetrical when viewed from dorsal side due to coiling of intestine. Operculum well formed, tail longer than the body. Epidermis of tail transparent.

23. The embryo assumes the tadpole form. It shows active spontaneous swimming. Horny larval teeth are formed. The posterior limb bud is identifiable. The operculum is closing over the gills. Tail three times the length of body. Epidermis transparent so that the gut is visible.

Comparison of the Species

The description of the stages here given is very similar to that given by Pollister and Moore, but this would follow since the stages are made to correspond. However, there are some differences found between *R. pipiens* and *R. sylvatica*. The most noticeable difference is in the gills and operculum. In *R. pipiens* the definite formation of the gills begins about the middle of stage 19. The operculum begins to form in stage 21 and is practically closed by stage 23. In fact, in some embryos of the same age the operculum is completely closed. In *R. sylvatica* the gills begin to form a little later and the operculum is beginning to form in stage 23. In other ways the species are very similar. But however slight the differences may be, this shows further than generalizations for one species cannot be made on the basis of another one even though they are closely related.

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Radiation of *Drosophila melanogaster* With Low-Intensity Ultra-Violet Light for One Complete Generation. III. Effect on Crossing-Over in the Second Chromosome of the Male.

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Introduction

Crossing-over in the male of *Drosophila melanogaster* formerly was supposed never to occur, but recent investigations have shown that it occasionally happens, particularly upon treatment with x-rays and heat. As yet, however, no literature has been found concerning the effect of ultra-violet light on this process.

The experiments here reported were undertaken to determine the effects upon crossing-over in the male of prolonged radiation with low-intensity ultra-violet light.

Review of Literature

Morgan (1912) found no crossing-over in the males of *Drosophila* between the black and vestigial loci. He (Morgan 1914) also pointed out that the F_2 generation contains no double recessives when one recessive enters from each P_1 parent. This he considered additional evidence of no crossing-over in the male.

Muller (1916) reported a case of spontaneous crossing-over in which all of the mature germ cells of a single male *Drosophila* were affected. Thus, all of the backcross offspring showed crossing-over.

Bridges and Morgan (1919) found a single crossover among the offspring of Star speck/purple speck males.

From the backcross of a single male *D. simulans* Sturtevant (1929) found one crossover between scarlet and peach among the 184 offspring.

In the control cultures of a *Drosophila* experiment by Patterson and Suche (1934) the frequency of crossovers was one to 8,239.

Kikkawa (1935) studied crossing-over in the male of *Drosophila virilis*. He performed an experiment continuous through ten generations and found three exceptional flies in a population of 38,598. He concluded that spontaneous crossing-over does occur in the male of *D. virilis*, though the frequency is very low.

Philip (1935) found the rate of double crossing-over and inverted crossing-over between the X- and Y-chromosome in the male *Drosophila* to be about one in 3,000.

These cases of crossing-over are the seven exceptions in which crossing-over of a spontaneous nature has been reported in the literature of *Drosophila* males (Whittinghill, 1937).

Friesen (1933) X-radiated males which were heterozygous for second or third chromosome characters. These were backcrossed, and 22 crossovers were obtained among a progeny of 561. He established the fact that crossing-over in males occurred in the central region of the

chromosome—in the same region where crossing-over is increased by X-radiation of females. He believed that there is an identical mechanism of crossing-over in both sexes.

Patterson and Suche (1934) found 77 crossovers in a population of 8,371 flies after exposure of heterozygous male parents in the larval stage to X-radiation. They concluded that X-radiation induced crossing-over in the male when applied to immature germ cells containing the diploid number of chromosomes.

Shull and Whittinghill (1934), working with heat, produced crossing-over in the male of *Drosophila*. They found three crossovers in the third chromosome of treated males among a population of 182 flies.

Philip (1934) investigated crossing-over between X- and Y-chromosomes during normal spermatogenesis and obtained three exceptional flies among a population of 997. The probability of mutations in accounting for these exceptions was eliminated by their frequency.

Friesen (1937) in further research on second and third chromosomes of X-radiated males found no effect of stock on crossing-over in males. In studying the effect of suppressors of the inversion type on crossing-over, he concluded that inversions were more feeble suppressors of crossing-over in males than in females.

Whittinghill (1937) induced crossing-over in *Drosophila* males by a temperature of 35° C. applied during the larval period.

Rifenburgh (1935) obtained crossing-over in the male between the black and vestigial loci following ultra-violet radiation of young larvae.

Methods

The source of the ultra-violet light for these experiments was a General Electric sun lamp (S2 Model K). Matings to be irradiated were made in 100 cc. beakers which were filled nearly to the top with Purdue culture medium (Rifenburgh, 1933). To prevent the medium from shrinking away from the sides of the beakers, water was added each day. Thus, the flies could not lay eggs below the surface of the medium where they might be shielded from the radiation. Both control cultures and experimental cultures were covered with cellophane. In addition, each control culture was shielded with a glass Petri plate presumably impervious to ultra-violet rays. A small electric fan was used to prevent an increase of temperature under the lamp. Room temperature was maintained at approximately 25° C. throughout the experiments.

In the first three experiments, wild-type males were mated to virgin b vg bw females. In the fourth and fifth experiments, wild-type males were mated to al b vg bw females. Parents for both treated matings and control matings were taken from the same stock cultures in order to insure identical heredity as nearly as possible. As soon as pupae appeared, the parents were removed from the beakers. The offspring were irradiated until their emergence from the pupa cases. Emergent flies

$\left(\frac{b \text{ vg } bw}{+} \text{ or } \frac{al \text{ b } vg \text{ bw}}{+} \right)$ were removed daily from the radiation, and the males backcrossed in ordinary culture bottles (in the room away from the lamp) to females of the recessive type. Each male was

TABLE I.—Emergence Record of Backcrosses (Second and Third Regions)

	Experimentals			Controls Under Lamp					Controls Not Under Lamp		
	II	IV	Total II & IV	I	II	IV	VA	Totals I, II, IV & VA	III	VB	Total III & VB
Number of Experiment.....											
Parental Types.....	16,010	4,293	20,303	11,514	9,403	5,470	9,228	35,615	23,712	9,179	32,891
Cross-overs b to vg.....	88	58	146	12	31	22	18	83	76	.....	76
Cross-overs vg to bw.....	20	.....	20	1	.....	10	.....	11	.....	.....	.....
Totals.....	16,118	4,351	20,469	11,527	9,434	5,502	9,247	35,710	23,788	9,179	32,967

mated to a group (3 or 4) of virgin females. On the following day each male was removed from the females and transferred to a new group of virgin females. This process was repeated every day with other groups until each male had been mated successively to five groups of females. Each group of females was placed successively in several (3 to 5) culture bottles and allowed to remain three days in each bottle. This procedure resulted in a relatively large number of cultures and an enormous progeny from each tested male.

In Experiment I a distance of 47 inches from the lower end of the bulb to the top of the medium was maintained. Twelve treated cultures and twelve control cultures were used. In starting these cultures, the flies were etherized for convenience in handling, placed in the beakers, and immediately subjected to the ultra-violet rays. Eight emergent F_1 treated males and eight emergent F_1 control males were backcrossed individually to $b\ vg\ bw$ females with a total of 400 backcross cultures. However, the experimental cultures were ruined by accident; therefore, only the 200 control cultures are included in the report.

In Experiment II the distance was 52 inches. Eighteen treated cultures and six control cultures were used. Males and females were placed in the beakers and allowed to recover from etherization for eight hours before exposure to radiation. Of the emergent F_1 progeny, 25 treated males and 11 control males were used for back-crossing. There was a total of 430 backcross cultures.

In order to investigate crossing-over of a spontaneous nature, a third series of controls was run with the same procedure and technique as in the controls of Experiment II, except that controls III were not placed under the ultra-violet lamp and were not subject to any radiation from it.

In Experiment IV the character *aristaless* was added to black vestigial brown, giving more complete coverage of the chromosome. The procedure and technique was the same as in the preceding experiments, except that the distance from bulb to medium was increased to 52½ inches. A total of 256 backcross cultures was obtained by back-crossing thirteen emergent F_1 treated males and ten emergent F_1 control males (heterozygous for *aristaless* black vestigial brown) to virgin $al\ b\ vg\ bw$ females.

In Experiment V two control populations were obtained. One set (VA) was run under the lamp; the second set (VB) was placed in the room away from the influence of the radiation. Twelve emergent F_1 males were tested from each set, giving a total of 263 backcross cultures.

In all the experiments reported in this paper, a grand total of 105 males were tested in 1,217 backcross cultures. These males produced a population of 89,146 offspring.

Results

Emergence tabulations for the backcross are shown in Table I. Parental and single crossover classes are represented, but there is no instance of double crossing-over.

Cross-over between the *aristaless* and black loci occurred but once, a single exceptional fly (a black vestigial brown female) being

TABLE II.—The Percentage of Recombination Between Black and Vestigial Loci

Experiment Number	Experimentals			Controls			Difference in %	D P. E. (diff)
	No ♂ Tested	Population	Recombination % b to vg	No ♂ Tested	Population	Recombination % b to vg		
I.....				8	11,527	.104 ± .0199		
II.....	25	16,118	.546 ± .039	11	9,434	.3286 ± .0398	.2174 ± .0557	3.9
III.....				14	23,788	.3195 ± .0236		
IV.....	13	4,351	1.333 ± .117	10	5,502	.3998 ± .0483	.9302 ± .1265	7.35
VA.....				12	9,247	.195 ± .03095		
VB.....				12	9,179			
II & IV.....	38	20,460	.713 ± .0397					
I, II, IV & VA.....				41	35,710	.232 ± .0171	.001 ± .025	.04
III & VB.....				26	32,967	.231 ± .01779		

found among the VA (under the lamp) controls. This one recombination occurred among a total radiated and control population of 28,459.

Percentages of recombination between the black and vestigial loci and also between the vestigial and brown loci are indicated in Tables II and III, respectively. Although crossing-over occurred in both regions among controls, there is a significantly higher percentage of recombination between these loci in the radiated cultures. Also, crossing-over is more frequent in the region of the spindle-fiber (between the black and vestigial loci than in either remote region.

Of the 38 treated males, nine (23.7%) showed crossing-over. Five (17%) of the 53 control males showed crossing-over. The total percentage of recombination is given in Table IV. The number of crossovers for each region produced by each of these males is shown in Table V. It is significant that crossovers did not appear in all cultures. Usually, several crossovers were found among the offspring of any one male or else crossing-over was completely absent (only four males of the 24 showing crossing-over produced less than three crossovers each.)

In Table VI the number of crossovers is given according to the age of the male at the time of mating. In the treated cultures and in controls as well, the number of crossovers produced varied with the age of the male, the greatest number appearing as a result of matings when the males were from two to seven days of age.

A total of 337 crossovers were found among the 89,146 backcross offspring. These were distributed as follows: 166 from experimental cultures, 95 from controls under the lamp, and 76 from controls not under the lamp.

Discussion

Crossing-over occurred in both radiated and control males. Treated males produced $.811 \pm .0423\%$ of recombination in comparison with $.246 \pm .0127\%$ from the control males. This gives a difference of $.565 \pm .0442\%$, which is certainly significant, it being 12.8 times its probable error.

The rate of recombination, not only in the experimental cultures but also in the controls, is high compared with records in the literature. Spontaneous crossing-over in males has been reported before in chance findings (Muller, 1916, Bridges and Morgan, 1919, Sturtevant, 1929) and also in researches directed at this possibility. The frequency was one in 3,000 (Philip, 1935), one in 8,239 (Patterson and Suche, 1934), and in another species, *D. virilis*, three in 38,598 (Kikkawa, 1933). These records are much lower than the frequency found in the work reported in this paper, which was 337 in 89,146 or about one in 264. The controls gave one in 404, and the radiated males produced one crossover for each 123 offspring.

Crossing-over in the left end of the second chromosome is so rare (one in 28,279) that it almost never occurs; nevertheless, the one instance shows that it is not impossible here. It is not known, however, just how far from the central region it happened since there was no marker between *aristaless* and *black*.

TABLE III.—The Percentage of Recombination Between Vestigial and Brown Loci

Experiment No.	Experimentals			Controls			Difference in %	D P. E. (diff)
	No ♂ Tested	Population	Recombination % vg to bw	No ♂ Tested	Population	Recombination % vg to bw		
I.....				8	11,527	.0087 ± .00586		
II.....	25	16,118	.1241 ± .0187	11	9,434			
III.....				14	23,788			
IV.....	13	4,351		10	5,502	.182 ± .03876		
VA.....				12	9,247			
VB.....				12	9,179			
II & IV.....	38	20,469	.0977 ± .01473					
I, II, IV & VA.....				41	35,710	.0308 ± .00623		
III & VB.....				26	32,967		.0308 ± .0062	4.9

TABLE IV.—Total Percentage of Recombination

	Experimentals	Controls	Difference	D P. E. (diff)
Number of Males Tested.....	38	86		
Population.....	20,469	69,030		
Recombination % al to b.....		.0108 ± .00728		
Recombination % b to vg.....	.713 ± .0397	.2303 ± .01228	.4827 ± .0416	11.6
Recombination % vz to bw.....	.0977 ± .01473	.0159 ± .00318	.0818 ± .0151	5.42
Total % of Recombination.....	.811 ± .0423	.246 ± .0127	.565 ± .0442	12.8
Grand Total % of Recombination, Experimentals and Controls Combined, .378 ± .0138				

TABLE V.—Crossovers by Males According to Region of Chromosome

Male Number		Experimental										Controls Under Lamp										Controls Not Under Lamp												
		Exp. II										Exp. IV		Exp. I		Exp. II		Exp. IV		Exp. VA		Total		Exp. III		Total								
		2X	4X	7X	10X	14X	15X	16X	18X	10X		4C	6C	10C	2C	5C	5C	10C	2XC	12XC		1C	2C	7C	11C	12C	13C							
												Total Exp.																						
1.																				1	1													
2.	1	3	16	6	22	11	20	9	58	146	3	3	6	11	20			22	18		83	7	1	10	16	41	1	76						
3.		7	6			2	4	1		20			1		10						11													
Totals	1	10	22	6	22	13	24	10	58	166	3	3	7	11	20	10	22	18		1	95	7	1	10	16	41	1	76						
Total Population Involved		20,469										35,710										32,967												
Grand Total of All Crossovers																						337												
Grand Total Population																						89,146												

Crossing-over occurred most frequently in the control region between the black and vestigial loci which includes the spindle-fiber attachment. More than nine-tenths of the crossing-over occurred in this region, and less than one-tenth in the region toward the right end of the chromosome (vestigial to brown), which covers a map distance about twice as great as the inclusive region.

In several males, crossing-over was not limited to a single region. With one exception (male 12XC), it never occurred in a remote region unless it also occurred in the inclusive region. Among males showing crossing-over in two regions, the frequency was higher for each male in the inclusive region with one exception (male 4X). These results agree with those of Whittinghill (1937) and Friesen (1933), who found most of the crossing-over in the inclusive region. However, occurrence in several males of crossing-over in two regions differs from the results of these two investigators who found it to be localized in one region only. It seems that Whittinghill was not justified in concluding that crossing-over is limited to only one region of the chromosome in any male. Perhaps he would not have reached such a conclusion had not the population in his experiments been so small (some 3,000 flies.)

The region most susceptible to modification of frequency rate (due to ultra-violet radiation) was a region (vg to bw) remote from the spindle-fiber attachment. The rate of crossing-over was increased more than six times in this region after treatment with ultra-violet light, whereas the rate was only slightly more than tripled in the inclusive region.

In regard to the two types of controls—i.e., under the lamp or not under the lamp—the rate for the first region was almost identical ($.232 \pm .071\%$ and $.231 \pm .0178\%$), but for the right limb of the chromosome, it was significantly different ($.0308 \pm .0062\%$ and zero). However, in view of the fact that there was no significant change in the inclusive region, it is suggested that perhaps the cause of the difference may not be the permeability of the glass cover to radiation but some other factor such as genes, or effect of stock, as it is sometimes called.

Effect of stock is suggested also by the fact that only certain males showed crossing-over (24 out of 105 tested), by the variation in number of exceptional offspring from such males (1 to 58), and by the rather large average number of such exceptional offspring per male (14).

The results of Friesen's work (1937) show no effect of stock, but here again the data seem insufficient owing to small populations.

Crossing-over in the male may be much the same process as in the female since ultra-violet radiation increases its rate in both sexes (Rifenburgh, 1935, as well as experiments here reported). However, its relative rate in the various parts of the chromosome differs in the sexes since in the male it is grouped around the spindle-fiber attachment—at least in the second chromosome.

Summary

1. More crossing-over occurred in radiated individuals than among controls. The difference was statistically significant, it being nearly 13 times its probable error.

TABLE VI.—Crossovers by Males According to Age at Mating

Male Number		Experimentals										Controls Under Lamp										Controls Not Under Lamp																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
		Exp. II					Exp. IV	Total	Exp. I		Exp. II	Exp. IV	Exp. VA	Total	Exp. III					Total																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
		2X	4X	7X	10X	14X			15X	16X					18X	4C	6C	10C	2C		5C	10C	2XC	12XC	1C	2C	7C	11C	12C	13C																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
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2. In most males, crossing-over was limited to the region including the spindle-fiber attachment.
3. In several males, crossing-over occurred in two regions.
4. Modification of crossover frequency was highest in a region of the chromosome remote from the spindle-fiber attachment.
5. Crossing-over in the second chromosome of the male differs from that in the female in respect to relative rates in different regions.
6. These results agree with those of certain other investigators who, working with various types of radiation, found crossing-over in the male concentrated in the region of the spindle-fiber attachment.
7. These results do not agree with those of certain other investigators who found crossing-over in a given male to occur in one region only.
8. These results disagree with those which led certain investigators to believe that crossover frequency in the male is more easily modified in the region including the spindle-fiber attachment than in remote regions.
9. Effect of stock is suggested as a probable factor in frequency of crossing-over.

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Intestinal Parasitism in a Group of University Students

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Introduction

During the past few years the writer has initiated studies concerning human parasite infections in Indiana, giving especial attention to the incidence of intestinal parasites as determined by laboratory diagnosis. A survey of the available literature was made (Headlee, 1937) which indicated that there were random case reports of parasite infections but that there were no valid data concerning the incidence of these infections in the general population of the state.

Subsequent to that time, laboratory examinations were made of over 1,300 persons residing in Indiana to determine the incidence of intestinal parasites, including both protozoa and helminths. The largest group examined, 1,200 persons, were patients of Longcliff State Hospital (Kmecz, 1939). Other examinations of persons included students of Purdue University and random examinations of persons in the locality of Lafayette, Indiana. A summary of the results of all these examinations of persons residing in Indiana was made by the writer (Headlee, 1939), but the group of out-of-state Purdue students was not included in that particular report. The present paper deals with the results of examinations of Purdue students as a group, including both residents of Indiana and non-resident students.

Materials and Methods

The data presented in this paper were obtained primarily by microscopic examination of fecal specimens, by which examinations both the cysts and trophozoites and the eggs of helminths could be detected. The stool specimens were collected in cardboard containers and examined within 24 hours after collection. Both unconcentrated and centrifugalized, concentrated preparations were examined from each fecal specimen, following the procedure outlined in a previous report (Headlee, 1939). In a few instances, the data were obtained by the identification of adult helminths that had been eliminated from the bowel, subsequent stool examinations indicating that no other worms were present.

Presentation of Data

Stools were examined from 213 students of Purdue University to determine the incidence of intestinal parasites. The stools were collected primarily through the cooperation of the Purdue University Student Health Service, but only relatively few students had visited the Health Service because of digestive complaints. Of the 213 students examined, 168 were males and 45 were females, 206 or 96.9% being between the ages 17 to 30 years, inclusive. The ages of the males ranged from 17 to 36 years; those of the females ranged from 17 to 60 years, inclusive. Of these students, 209 were from 17 states of the United States, 162 or 76.5% of the total number examined being from

Indiana and 47 or 22% of the total examined being from the 16 other states. Of the four remaining students, one was from the District of Columbia, one from Mexico, and two from Venezuela. The 162 students who were residents of Indiana were from 59 of the 92 counties of the state. Thirty-nine of these students were from Tippecanoe County, this being the largest number from any single county. Sixty-two of the 213 persons examined or 29.1% were residents of rural areas.

The species of parasites encountered and the percentage incidence of each were as follows: *Endamoeba histolytica*, 2.8; *Endamoeba coli*, 19.7; *Endolimax nana*, 30.5; *Iodamoeba bütschlii*, 1.4; *Giardia lamblia*, 2.3; *Chilomastix mesnili*, 0.5; *Ascaris lumbricoides*, 0.9; *Trichuris trichiura*, 0.9; *Necator americanus*, 0.5; *Enterobius vermicularis*, 1.9; *Hymenolepis nana*, 0.5. Further examination of the data showed that 91 individuals or 42.7% were infected with protozoa; 10 individuals or 4.7% were infected with helminths, and 4 persons or 1.9% harbored infections of both protozoa and helminths. Of the 213 students examined, 97 or 45.5% were infected with one or more species of protozoa, helminths, or both protozoa and helminths. These data are presented in detail in Table I.

Discussion and Conclusions

Among the six students harboring infections of *Endamoeba histolytica*, only one person is recorded as having symptoms of amebic dysentery. It may be considered that the others found infected with this organism were carriers. It must not be overlooked that these individuals are a source of material for the spread of infections with this organism and that the particular strain might prove to be pathogenic for other persons infected.

Wenrich, Stabler, and Arnett (1935) reported their findings from the examination of 1,060 students of a professional school of Philadelphia, Pennsylvania, for infections with intestinal protozoa. A comparison of the data from that survey with that of the present survey is given in Table II.

These two sets of data can not readily be compared because of a difference in methods used. In the Philadelphia survey wet smears were examined as in the present survey, but concentrated preparations were not examined. In addition to the wet preparations these workers examined smears stained with iron alum-haematoxylin. This method gave results 17.7% higher for total infections than the wet preparations alone. By this method the incidence of *Endamoeba histolytica*, based on the examination of 700 persons, was raised 1.4%. Taking this into consideration, the incidence would be 2.7% for the wet smears. This compares favorably with the 2.8% obtained in the present survey. The total incidence of protozoal infections and the incidences of *Endamoeba coli*, *Endolimax nana*, and *Iodamoeba bütschlii* were higher in the present survey than those of the Philadelphia survey; the incidences of *Endamoeba histolytica*, *Dientamoeba*, *Giardia* and *Chilomastix* were lower.

The incidence of helminths was low, but we would hardly expect to find a high incidence of these parasites in a population group of the type examined. The species most frequently encountered was *Enterobius*

TABLE I.—The Incidence of Intestinal Parasites Among Students of Purdue University

Age.....	17-20 Years						21-30 Years						31- Years						Total									
	M			F			M & F			M			F			M & F			M			F			M & F			
	No.	%		No.	%		No.	%		No.	%		No.	%		No.	%		No.	%		No.	%		No.	%		
Sex.....																												
End. hist. End. coli. Endolimax nana. Iodamoeba. Giardia. Chilomastix. Ascaris. Trichuris. Necator. Enterobius. Hymenolepis. Total infected with protozoa. Total infected with helminths. Total infected with both protozoa and helminths.	2	2.8	1	5.9	3	3.4	2	2.2	1	3.8	3	2.6							4	2.4	2	4.4	6	2.8				
	9	12.5	2	11.8	11	12.4	23	25.3	6	23.1	29	24.8	1	20.0	1	50.0	2	28.6	33	19.6	9	20.0	42	19.7				
	26	36.1	5	29.4	31	34.8	27	29.7	5	19.2	32	27.4	1	20.0	1	50.0	2	28.6	54	32.1	11	24.4	65	30.5				
	1	1.4			1	1.1	1	1.1	1	3.8	2	1.7							2	1.1	1	2.2	3	1.4				
	2	2.8	1	5.9	3	3.4	2	2.2			2	1.7							4	2.4	1	2.2	5	2.3				
			1	5.9	1	1.1																						
	1	1.4			1	1.1	1	1.1			1	0.9							2	1.1								
	1	1.4			1	1.1			1	3.8	1	0.9							1	0.6	1	2.2	2	0.9				
								1	1.1										1	0.6					1	0.5		
				2	11.8	2	2.2	2	2.2			2	1.7						2	1.1	2	4.4	4	1.9				
										1	1.1		1	0.9						1	0.6				1	0.5		
		30	41.7	6	35.3	36	40.4	42	46.1	10	38.5	52	44.4	2	40.0	1	50.0	3	42.9	74	44.0	17	37.8	91	42.7			
		2	2.8	2	11.8	4	4.5	5	5.5	1	3.8	6	5.1							7	4.2	3	6.7	10	4.7			
	1	1.4			1	1.1	3	3.3			3	2.6							4	2.4			4	1.9				
Total infected.....	31	43.1	8	47.1	39	43.8	44	48.4	11	42.3	55	47.0	2	40.0	1	50.0	3	42.9	77	45.8	20	44.4	97	45.5				
Total examined.....	72		17		89		91		26		117		5		2		7		168		45		213					

TABLE II.—Comparison of the Incidence of Protozoal Infections Among College Students of Two Institutions in the Temperate Region

	Philadelphia Professional School		Purdue University	
	Number	Per cent	Number	Per cent
<i>Endamoeba histolytica</i>	43	4.1	6	2.8
<i>Endamoeba coli</i>	154	14.5	42	19.7
<i>Endolimax nana</i>	121	11.4	65	30.5
<i>Iodamoeba bütschlii</i>	11	1.0	3	1.4
<i>Dientamoeba fragilis</i>	45	4.3	0	0.0
<i>Giardia lamblia</i>	79	7.5	5	2.3
<i>Chilomastix mesnili</i>	10	0.94	1	0.5
Total infected with protozoa....	366	34.5	91	42.7
Number examined.....	1,060		213	

vermicularis. No doubt the incidence of this parasite would have been considerably higher if perianal scrapings had been examined.

Although the incidence of pathogenic species was relatively low, it is the opinion of the writer that it would be very much worth while to give more attention to parasite infections and to recognize the fact that these infections may often be the cause of an illness attributed to other etiological agents.

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Modified Respiratory Movements During Egg Laying in the Hen

N. C. WHEELER, W. C. RANDALL, and W. A. HIESTAND, Purdue University

During some experimental work on the chicken, *Gallus domesticus*, a definite pattern of irregular breathing movements was noticed. A hen, placed in a cabinet¹ preparatory to raising the external temperature, exhibited irregular respiratory rhythm. The hen was subjected to an external temperature of 32°C. The cloacal temperature had increased 0.25°C. above the normal temperature, i.e., the temperature of the cloaca before the application of the external heat.

The normal record of the respiratory movements of the hen is quite similar to that of other vertebrates, the inspiration requiring the greater portion of the time for the respiratory cycle. In Fig. 1, A, the



Fig. 1. Respiratory movements during egg laying in the hen. The down stroke of the tambour indicates inspiration.

- A. Normal respirations of first hen (40 to 50 per min.).
- B. Irregular respiratory movements during egg laying. The arrow indicates time of deposition of egg.
- C. Normal respirations of second hen (28 per min.).
- D. Irregular respiratory movements during egg laying. The arrow indicates time of deposition of egg.
- E. Time intervals, 10 sec.

¹Hiestand, W. A., and W. C. Randall, 1939. An apparatus for raising the body temperature of small animals. *Amer. Mid. Natur.* 23:214.

respiratory rate was 40 to 50 per minute and is quite normal for a hen under the increased environmental temperature.

The irregular respiratory rhythm, as shown in Fig. 1, B, was interesting in that following a series of uniform movements apnea occurred at the end of certain expirations. A protrusion of the abdomen indicated the appearance of an egg. As soon as the egg was deposited, as indicated by the arrow, the breathing became regular but was dyspneic during the next 20 seconds after which the amplitude became normal.

Several days later, at the beginning of another experiment, the same type of respiratory movements was observed. This recording (Fig. 1, D) was made at room temperature and is so similar to that made at the higher temperature that the two recordings are presented as representing the character of the breathing movements of a hen while laying an egg. The normal respiratory rate of this hen was 28 per minute.

Both records show essentially the same peculiarities in respiratory rhythm, namely, alternate periods of eupnea and apnea, the latter phase occurring at the end of an expiration and persisting for approximately 3 to 4 seconds. In record 1, B, the dyspneic respiration following expulsion of the egg might be made accountable by an accumulation of an excess of CO_2 during the previous period or by the increase in body temperature of the bird in the fever cabinet. The former explanation is the more probable since high body temperature ordinarily causes an increased rate rather than an increased amplitude of respiratory movements in chickens.

An analysis of the modified respiration of the hen during egg laying indicates that periodic held expirations either facilitate mechanically the passage of the egg through the distal portion of the genital tract or occurs as a result of mechanical conditions induced by the passage of the egg.

Some Gross Anatomical Relations of the Male Urogenital System and Other Internal Organs in *Eumeces fasciatus*.

ALBERT E. REYNOLDS, DePauw University¹

Introduction

While the attack on the problems of zoology proceeds with increasing intensity over an ever-widening front, it remains true that, among vertebrates, the reptiles are a relatively neglected group. Phylogenetic position, physiological considerations centering around poikilothermism, or difficulty of capture or keeping may militate toward this neglect. Another factor may well be that the exact anatomy of most American reptiles has not been worked out. For the experimentalist, therefore, they do not constitute a part of an explored field from which he may select an experimental medium. It is in the hope that a small contribution may be made toward the placing on record of anatomical data on native reptiles that the observations reported here on the red-headed skink, *Eumeces fasciatus*, are presented.

The scincoid *Eumeces fasciatus* may be regarded as a fairly representative American lizard as it has a widespread distribution in the United States (Stejneger and Barbour, 1939; Taylor, 1935). My interest in the animal centered around certain physiological processes and their seasonal variations, approached in part from the standpoint of histological study. For proper prosecution of such studies, a background of knowledge of the gross anatomy had to be developed, and it is to the reporting of some of the gross anatomical relations of these animals that this paper is devoted.

Material

The skinks that have been examined have been adults or animals only slightly immature. While a few of the animals observed have been from the several counties around the Greencastle (Indiana) area, specimens have also been obtained from Arkansas, Missouri, Tennessee, and Florida. The total number of animals that have passed under scrutiny number several score. Such general statements as occur in this paper are based on the total experience gained in working with these animals; the more specific statements are based on five specimens, animal numbers 4, 53, 54, 55, and 210.

Methods

In dissection the usual approach by means of a ventral incision through the body wall was employed. Due to extensive subcutaneous connective tissue, the skin is firmly adherent to the subjacent muscular coat.

¹Approximately half the work upon which this paper is based was done at the Hull Zoological Laboratory, The University of Chicago.

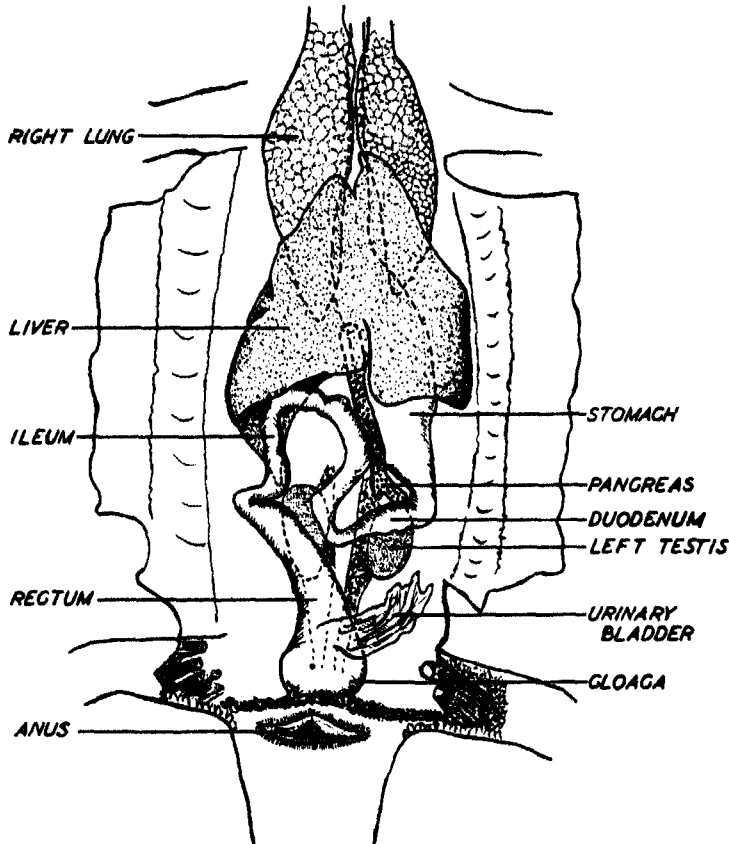


Fig. 1. *Eumeces fasciatus* No. 4. Ventral dissection of young male drawn to scale, showing chief abdominal viscera. For relations, limb outlines, cut muscles, and flaps of body wall tissue shown. (x3)

In *Eumeces fasciatus* the skin is complicated not only by epidermal scales but also by the underlying bony osteoderms of dermal origin. After parting the skin, another incision is passed through the muscular coat (mostly the *M. rectus abdominis*). Lateral cuts at the limb levels then permitted pinning back of the flaps of body wall tissue. Further dissection, such as removal of muscle, bone, etc., at the girdle levels was carried out as needed.

Figures were drawn to scale, and in each case different degrees of dissection reveal different aspects of the internal anatomy. Figure 1 shows organs visible after opening up the coelom with a minimum of organ displacement. The view seen in Figure 2 required more dissection; that in Figure 3, still more.

Both freshly killed and preserved animals have been examined. All reference to color and appearance is based on the fresh condition. As aids to study, the binocular dissecting microscope and micrometer cali-

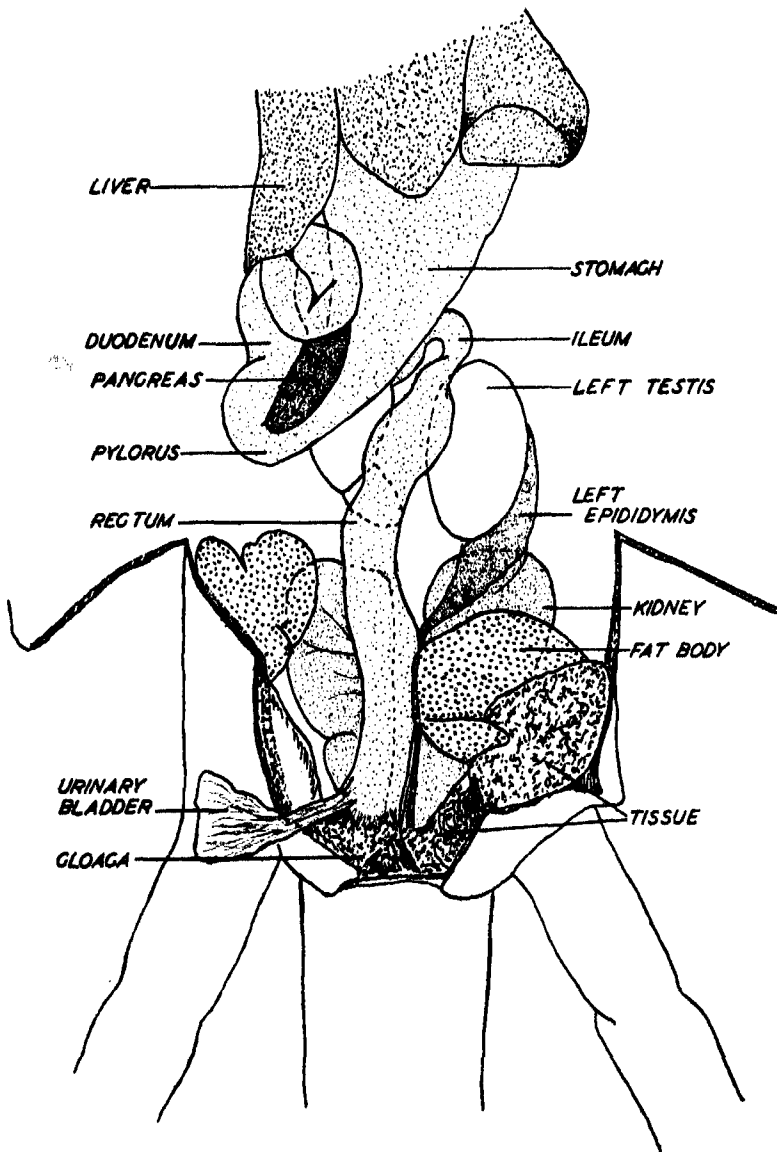


Fig. 2. *Eumeces fasciatus* No. 210. Ventral dissection of mature male, showing part of abdominal viscera and most of urogenital system. Area labelled "tissue" consists of residual cut ends of muscle, connective tissue, etc. (x8)

pers were extensively used. Where measurements are expressed in metric units, they do not represent numerical averages or statistical means but are the single measurements of representative specimens.

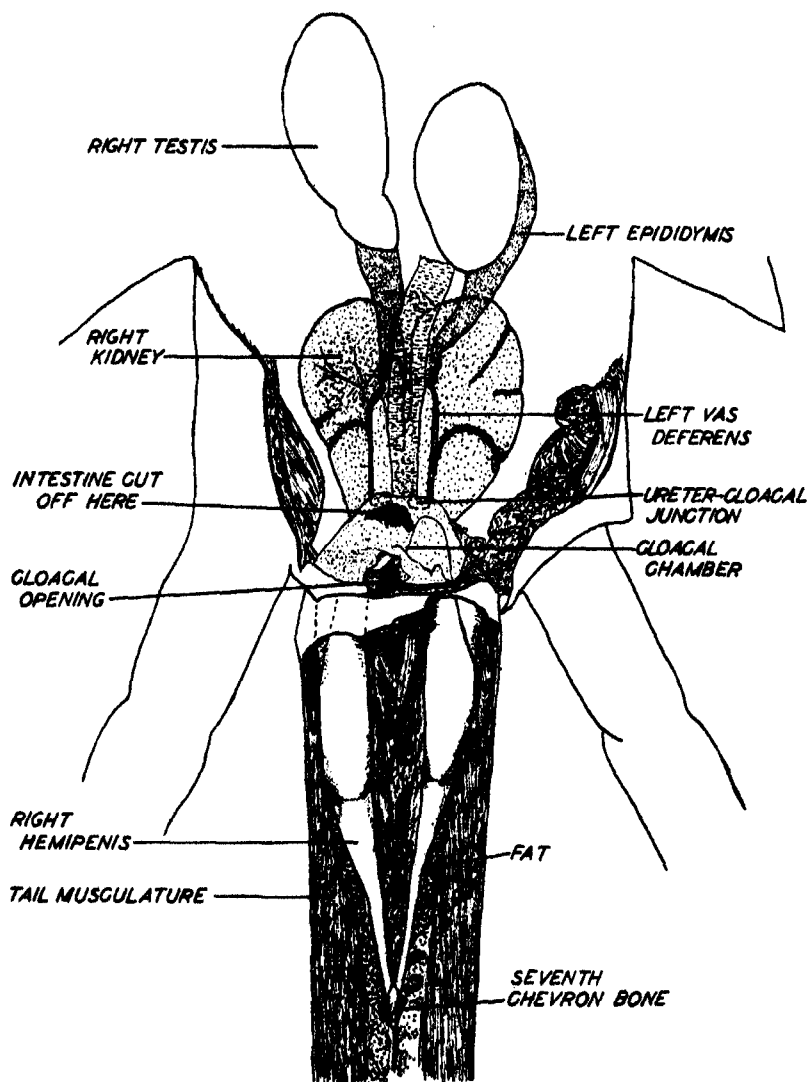


Fig. 3. Specimen No. 210 with viscera removed to reveal further the urogenital organs, and ventral side of tail removed to show hemipenial relations. (x8)

This report is concerned for the most part with the abdominal viscera and the urogenital system in the male. Emphasis was laid on organ relations.

Literature

Accounts of lizard anatomy are not numerous in English, as Davis (1934) implies. Volume II of Parker and Haswell's (1930) text contains

a discussion based on the European genus *Lacerta*, and chiefly on *L. viridis*. On American forms Adams (1938) gives figures and a brief description of the iguanid *Sceloporus*, and Davis (1934) has written a laboratory guide on another iguanid, *Crotaphytus*. Probably the most comprehensive reference work on lizard anatomy is that of C. K. Hoffman, in the old classic, Bronn's *Thierreich*. The excellent account of

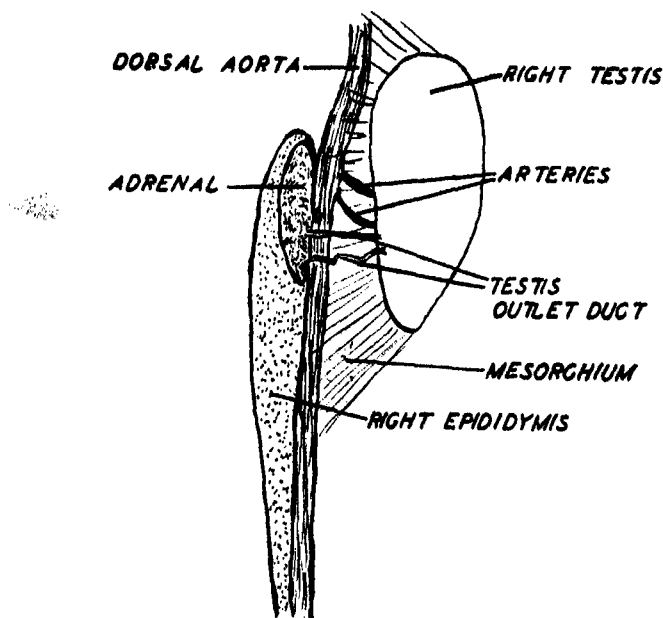


Fig. 4. Right testis of *E. fasciatus* No. 53 displaced to the left, to illustrate testicular blood supply and relations of adrenal gland, epididymis, dorsal aorta, and testis. (x5)

Kraus (1921) is based on *Lacerta agilis* and is written from the standpoint of histology but contains much gross anatomical material. A most exhaustive treatment, when completed, will be that of Bolk et al (1931), and Kükenthal (1931) bases discussion on the interesting primitive lizard, *Sphenodon*.

Observations

General arrangement of parts.—When the coelom or pleuro-peritoneal cavity is opened as described above, a typically vertebrate arrangement of parts is seen. The sections below describe these parts in more accurate terms.

1. **Heart, lungs, trachea.**—In the anterior end of such a dissection the removal of muscle and bone of the pectoral region reveals that the heart lies directly dorsal to the pectoral girdle. The lungs join the bronchial tubes just dorsal to the heart. The trachea is quite long, its walls containing the characteristic cartilaginous rings. It extends anteriorly ventral to the oesophagus.

The lungs arise at the junction with bronchical tubes, at the heart level, and extend posteriorly into the coelomic cavity (Fig. 1). In animal No. 4 the total length of the lungs is 11.0 mm., their posterior terminations lying 4.0 mm. posterior to the origin of the cardiac end of the stomach.

2. **The digestive tube.**—The oesophagus lies in the median line in a somewhat dorsal position, running anteriorly dorsal to the trachea and being flanked by the lungs posteriorly. The oesophagus enlarges to form cardiac stomach at a point 4.0 mm. anterior to the posterior tip of the lungs in animal No. 4 (Fig. 1).

From the above-mentioned origin of cardiac stomach to the pyloric sphincter, the stomach of No. 4 is 15.0 mm. in length. Specific stomach shape is subject to considerable variation; in general, however, the greatest diameter is near the cardiac end, with a gradual decrease of diameter to the pylorus. The stomach of No. 210 (Fig. 2) conforms to this; that of No. 4 (Fig. 1) is somewhat modified. In No. 4 the stomach lies somewhat to the left of the median line, and almost antero-posteriorly. In No. 210 (Fig. 2), it lies more obliquely. A slight obliqueness of stomach position, from anterior left to posterior right, is the general rule. Exaggerated obliqueness is generally more illusory than real because of differential curvature. The lateral surface of greater curvature may be fairly oblique, especially posteriorly; the medial surface of lesser curvature is much less oblique.

The pylorus is usually evident as a constriction terminating the stomach. The posterior edge of the intestinal tube here is 4.3 mm. anterior to the anterior edge of the kidneys in No. 210 and 16.8 mm. anterior to the ventro-anterior lip of the anus.

From the pylorus the initial part of the small intestine, the duodenum, extends forward, forming with the stomach the J-shaped loop characteristic of vertebrates. The duodenum extends as far forward as the posterior limit of the liver. The anterior edge of the tube at this point in No. 210 is 23.5 mm. anterior to the ventro-anterior anal lip. Hence, it exhibits a difference in level, as compared with pylorus of 6.7 mm., which gives an approximate length for the duodenum. In No. 210 the outer edge of the duodenum is 7.3 mm. to the right of the body midline. (Fig. 2).

From the most anterior level near the liver, the ileum then extends backwards to the rectum. The ileum usually exhibits 2 or 3 loops or curves, the exact arrangement of which is variable, those shown in Figures 1 and 2 being characteristic. In No. 4 the combined length of small intestine, duodenum, and ileum is 24.0 mm. Diameters were not measured but are drawn to scale in the figures.

From the point where the ileum enlarges to form it to the point where it gives rise to the globular cloaca (Figs. 1, 2) the rectum is 9.0 mm. long in No. 4. It is 3.5 mm. in diameter near its posterior end in No. 54. In *Lacerta*, Parker (1884) and Parker and Haswell (1930) describe a caecum at the junction of ileum and rectum. Adams (1938) figures but does not describe such a caecum for *Sceloporus*. Davis (1934) mentions one for *Crotaphytus* as a thin walled enlargement. An asymmetry of rectal expansion is implied in these descriptions. I can find no

similar structure in *Eumeces*, and any caecal capacity here must be largely capacity for a symmetrical enlargement of the anterior end of the rectum (Fig. 2).

The cloaca is the most posterior region of the digestive tube, of functional significance as excurrent pathways for products not only of the digestive but also of reproductive and urinary systems as well. It is usually of greater diameter than the large intestine, often globular in shape. The study of its posterior chambers is properly a histological one and will be reported later. It opens to the exterior at the anus, a transverse slit (Fig. 1) having in No. 4 a maximum width of 5.5 mm. It coincides in level with the posterior borders of the limbs.

3. **Digestive glands.**—The pancreas is somewhat elongate, lying between the stomach and duodenum and extending forward toward the liver. The latter organ is conspicuous, occupying much coelomic space and ventrally located, thus overlying some organs when viewed ventrally (Fig. 1). In No. 4, from the most anterior tip on the left side of the liver to the posterior border of the same side, the measurement is 11.0 mm. and, from the same tip to the level of the most posterior tip on the right side (concealed by intestine, Fig. 1), 16.5 mm. In No. 210, the right lobe of the liver lies at the same level as the anterior extension of the duodenum, the central lobe terminates 4.3 mm. anterior to this, and the left lobe in turn is 2.8 mm. (with tip turned down, Fig. 2) longer than the central one. The width of the liver is approximately that of the coelomic cavity, tapering anteriorly.

4. **Testis.**—The compact cylindrical testis appears more or less oval when viewed ventrally. It is light yellow in color and lies suspended in the bilateral mesenteric fold, or mesorchium, close to the dorsal body wall.

The lizard testis seems to exhibit typically an asymmetry of antero-posterior level, the right one lying anterior to the left. Such is the case in *Sceloporus* (Adams, 1938), *L. viridis* (Parker, 1884), and *L. agilis* (Kraus, 1921). The testis of *Eumeces fasciatus* conforms to this scheme (Figs. 1 and 2). In No. 54, the posterior borders of the testis are 1.5 mm. apart in level. In No. 210, the posterior end of the right testis is 0.8 mm. anterior to the same end of the left, but because of greater length its anterior end is 3.0 mm. in front of the anterior end of the left.

Size, shape, and weight of the testis is subject to considerable variation, which is not only among individuals but may also be bilateral in the same individual. Thus, in No. 54, the right testis measures 4.9 mm. x 1.9 mm.; the left 5.0 mm. x 2.0 mm. In No. 210, the right testis is 10.0 mm. x 4.0 mm.; the left 7.4 mm. x 4.0 mm. (Fig. 2). The right testis of No. 53 is 5.0 mm. long.

The testis occupies a quite dorsal position, being overlaid only by the adrenal gland and part of the epididymis (Fig. 3; 4). In No. 53, the testicular blood supply consists of two small branches of the dorsal aorta, the anterior branch entering the testis 2.8 mm. from its anterior end. (Fig. 4) Bilaterally the testis lies with medial borders a short distance from the body midline, the lateral border of the left testis lying 5.0 mm. to the left of the median line in No. 210.

As to antero-posterior level, the testis lies near the pylorus (Fig. 1, No. 4) and near the anterior end of the rectum (Figs. 1, 2). The left testis of No. 54 lies 2.0 mm. in front of the anterior border of the left kidney. In No. 210, the posterior edge of the right testis is 1.9 mm., of the left testis 1.1 mm.; anterior to the foremost edge of the kidney. In the same animal the anterior edge of the left testis is 21.0 mm. anterior to the ventro-anterior lip of the anus, 8.5 mm. in front of the anterior edge of the kidneys, thus extending 4.2 mm. farther forward than the pyloric level (Fig. 2). The posterior edge of the right testis in No. 210 is 14.4 mm. in front of the same anal lip, the posterior edge of the left testis, 13.6 mm. These are then 2.4 mm. and 3.6 mm., respectively, from the pyloric level.

5. **Kidneys.**—The kidneys lie flush against the dorsal muscular body wall, far back posteriorly, in the usual retroperitoneal position. The anterior edge of the kidney, in No. 210, lies 12.5 mm. in front of the antero-ventral anal lip. Each single kidney may be likened to the shape of a right triangle, where the median edge forms a right angle with the anterior edge and the lateral edge forms the hypotenuse. The apex, represented by the posterior tip of the kidney, is far posterior, extending about 2.0 mm. to 3.0 mm. posterior to the level of the anus, lying imbedded in muscle close to the vertebral column. Morphologically the two kidneys are distinct anteriorly, but they become anatomically connected about midway of the length of the two kidneys. Indentations on the lateral edges and grooves on the ventral surfaces mark lobulations of each kidney (Fig. 3), which is a "true kidney" or metanephros.

In animal No. 54, the kidney extends to within 2.0 mm. of the posterior border of the left testis, and the greatest width of the left kidney is 2.5 mm. As indicated above, the kidney in No. 210 comes to within 1.9 mm. and 1.1 mm. of the respective right and left testes and 4.3 mm. of the duodenum. Also in No. 210, the front border of the kidneys extend 12.5 mm. anterior to the ventro-anterior anal lip; hence, they are about 14.5 mm. long to posterior tip. The front edge of the kidney in No. 210 is 8.5 mm. from the posterior edge of the left testis. A band of material is seen passing along covering the medial surfaces of the kidneys in No. 210 (Fig. 3) which consists of blood vessels, peritoneum, and cut mesenteric material.

6. **Other urogenital structures; the adrenal gland.**—The epididymis is fusiform in shape. It widens rapidly from the anterior end to a maximum, then narrows down more gradually to the origin from it of the vas deferens (Fig. 3). The organ is suspended in a fold of the mesorchium, dorsal and lateral to the testis. In animal No. 54, the anterior end of the epididymis is 0.8 mm. posterior to the front end of the right testis; in No. 53, this distance is 1.5 mm.; also on the right side. As seen from the ventral side, the organ emerges from under the lateral border of the left testis 2.3 mm. posterior to the anterior edge of the latter organ in No. 210. The maximum width of the right epididymis in No. 54 is 0.8 mm., and length of both epididymis and vas deferens is 7.8 mm., the two vasa deferentia entering the cloaca at points 1.8 mm. apart. The epididymis extends posteriorly, then obliquely across the anterior ventral

surface of the kidney; then it gives rise to the vas deferens. The latter tube exhibits a few convolutions at its anterior end, then extends posteriorly near the medial edge on the ventral surface of the kidney.

The adrenal gland, golden yellow in color, lies on the medio-ventral surface of the epididymis and is inseparably bound up in the epididymal capsule (Fig. 4).

The ureter is not easily observed, as it is not visible as a distinct tube. It arises at about the last convolution of the vas deferens, and extends as a ridge on the ventral renal surface medial to the vas deferens. It does not emerge as a definite tube to enter the cloaca, as cloacal wall and kidney surface are so closely approximated that an extremely short connection is effected (Fig. 3). Whether the ureter and vas deferens on a side unite before joining the cloaca was not determined.

7. **Hemipenis.**—The copulatory sac or hemipenis may be considered a posterior evagination of the cloacal wall. Surrounded by a sheath, the hemipenis lies among the muscles of the ventro-lateral region of the tail. Anteriorly the organ connects with the posterior cloacal wall near the ventro-lateral corners. At approximately half the total length posterior, the organ changes character, the posterior part undoubtedly being muscular, the anterior part the saccular intromittent organ itself. The entire organ slants medially and dorsally, finally effecting a connection with the seventh chevron bone of the tail. This must be associated with the eleventh caudal vertebra since Taylor (1935) states that chevron bones begin on the fourth caudal vertebra.

8. **Fat storage.**—The corpora adiposa are bilateral masses of fatty tissue lying at the approximate coelomic level of the anterior half of the kidney (Figs. 2, 3). These fat bodies are the usual yellow color and vary greatly in size and weight. Their position is latero-ventral, mostly in front of but partly lying under (dorsal to) the pubic part of the pelvic girdle. It may be of considerable interest to point out that in *E. fasciatus* the fat bodies may be outclassed by the tail as sites of fat deposition. Large masses of fat, segmentally laid down, were dissected from the tail region of No. 210 in preparing it for the drawing seen in Figure 3. Remaining fat is shown in the figure.

Summary

It has been demonstrated that the abdominal viscera and the urogenital system of *Eumeces fasciatus* is arranged in a typical vertebrate manner. The arrangement of these organs and part-to-part relationships have been described in rather exact terms and supplemented by the presentation of figures.

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Notes on Indiana Noctuidae

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The family Noctuidae has not previously been considered in the surveys of the insect fauna of Indiana. It would, therefore, seem advisable to list the species known to occur in the state and to provide such notes as would add to our knowledge of the various species, particularly concerning those of common occurrence or economic importance.

The moth collections have been largely based on light and bait trap examinations. However, many species have been captured by other means of collection, and many have been reared. Since some species are common throughout the season or may be taken in large numbers throughout various seasonal periods, general notes are often more valuable than actual collection dates. Where very common species which are somewhat numerous at some time or other during the year are discussed, the information is given in general terms which will indicate the insect's abundance and time of appearance. Less common species are attributed the date of collection information.¹ Unless otherwise stated, all collections are attributable to the author. The species are numbered according to Barnes' Check List.²

Genus HELIOTHIS Ochs.

H. phylloxiphaga G. & R. (1089).

Var. luteitinctus Grt. DeKalb Co., Aug. 11; Tippecanoe Co., Aug. 20 (P.L.)³

H. armiger Hbn. (1090). Corn earworm, tomato fruitworm, cotton bollworm, and tobacco budworm. Common and destructive during all years in southern part of state, in late fall migrating into northern Indiana in outbreak numbers during some seasons. Commonly found breeding throughout the fall in greenhouses. DeKalb Co., Aug. 1-Oct. 19; Starke Co., April 21 (J.J.D.); Steuben Co., Sept. 6 (G.R.); Tippecanoe Co., Aug. 13 (J.J.D.), Oct. 5 (P.S.C.).

Genus LYGRANTHOECIA G. & R.

L. marginata Haw. (1180). DeKalb Co., June 20-Aug. 12; Tippecanoe Co., June 23 (J.J.D.).

¹Determinations of all but the most common and easily recognized species were made by W. T. M. Forbes and J. McDunnough.

²Barnes, Wm., and J. McDunnough. Check list of the Lepidoptera of boreal America.

³Specimens collected by others than the author are followed by their initials as follows: (J.J.D.) J. J. Davis, (G.E.M.) G. E. Marshall, (G.E.G.) G. E. Gould, (P.S.C.) Purdue Student Collection, (P.L.) P. Luginbill, (A.F.S.) A. F. Satterthwait, (C.R.C.) C. R. Cleveland, (G.R.) G. Ryan, (S.L.M.) S. L. Mason, (F.A.F.) F. A. Fenton, (A.W.T.) A. W. Trippel.

Genus POROSAGROTIS Sm.

P. vetusta Wlk. (1234). Spotted-legged cutworm. Reported to be typically associated with sandy country.⁴ DeKalb Co., Aug. 8; Tippecanoe Co., Nov. 11 (J.J.D.).

Genus EUXOA Hbn.

E. quadridentata G. & R. (1247). DeKalb Co., Sept. 1.

E. punctigera Wlk. (1286). Scarce. Washington Co., July 1 (J.J.D.).

E. velleripennis Grt. (1291). Common on goldenrod blossoms. DeKalb Co., Sept. 12-23.

E. messoria Harris. (1304). Dark-sided cutworm. A common and destructive species. DeKalb Co., July 12-Oct. 19; Tippecanoe Co., July 3, 13, 31 (J.J.D.).

E. fumalis Grt. (1312).

Var. *vestitura* Sm. This variety only has been taken. DeKalb Co., June 23.

E. tessellata Harris. (1329). Striped cutworm. Common. Less numerous than *messoria* except on gravelly or sandy soils. Dark form also common. DeKalb Co., July 3-Aug. 14; Elkhart Co., June 18 (A.W.T.); Steuben Co., July 11, 14, 28 (G.R.); Tippecanoe Co., emerged June 22, 27 (J.J.D.); Wabash Co., June 18 (A.W.T.).

E. albipennis Grt. (1341). Tippecanoe Co., Sept. 14 (J.J.D.).

E. ochrogaster Gn. (1363). Tippecanoe Co., July 23, Aug. 25 (J.J.D.).

Genus FELTIA Wlk.

F. gladiaria Morr. (1395). Clay-backed cutworm. Abundant from early September through October. DeKalb Co., Sept. 9-Oct. 22; Tippecanoe Co., Sept. 25, Oct. 5 (J.J.D.), Oct. 9 (P.S.C.).

F. venerabilis Wlk. (1397). Dusky cutworm. DeKalb Co., Sept. 3; Tippecanoe Co., Sept. 9 (P.S.C.), Oct. 5 (J.J.D.).

F. ducens Wlk. (1402). Dingy cutworm. Common and destructive. Numerous from August through October. DeKalb Co., Aug. 6-Oct. 19; Gibson Co., emerged Sept. 18 (J.J.D.); Greene Co., emerged Aug. 21, Sept. 9, 17, 19, Oct. 4 (J.J.D.); Monroe Co., emerged Sept. 1 (J.J.D.); Steuben Co., Aug. 4, Sept. 1 (G.R.); Tippecanoe Co., emerged Aug. 3-Sept. 21 (J.J.D.); Vanderburgh Co., emerged Sept. 21 (J.J.D.).

F. subgothica Haw. (1403). Dingy cutworm. Less numerous than *ducens*; occurring at approximately the same time. Clinton Co., Sept. 2 (J.J.D.); DeKalb Co., Aug. 15-Sept. 13; Gibson Co., Aug. 30, Sept. 18 (J.J.D.); Greene Co., emerged Aug. 6, Sept. 12, 13, 19 (J.J.D.); Steuben Co., Aug. 9, 17 (G.R.); Tippecanoe Co., Aug. 13, 27 (P.S.C.), Sept. 3 (J.J.D.).

F. herilis Grt. (1404). DeKalb Co., Aug. 28-Sept. 15; Steuben Co., Aug. 7 (G.R.).

F. volubilis Harv. (1409). DeKalb Co., May 29, 31; Tippecanoe Co., May 11 (P.S.C.).

⁴Forbes, W. T. M., 1926. A check list of the insects of New York. Cornell Univ. Agric. Exp. Sta., Mem. No. 101. 1926.

F. annexa Treit. (1418). Granulated cutworm. DeKalb Co., Aug. 23; Orange Co., Aug. 21 (G.E.M.).

F. malefida Gn. (1414). Pale-sided cutworm. DeKalb Co., July 28-Sept. 3.

Genus AGROTIS Ochs.

A. badinodis Grt. (1415). Spotted-sided cutworm. Common. DeKalb Co., Sept. 2, 10, 23; Steuben Co., Aug. 4 (G.R.); Tippecanoe Co., Aug. 18-Sept. 29 (J.J.D.).

A. ypsilon Rott. (1422). Greasy cutworm, black cutworm, and overflow worm. One of the most numerous and destructive cutworms, particularly in muck soils and in poorly drained areas. Numerous from May to October. DeKalb Co., May 3-Oct. 14; Gibson Co., emerged Aug. 4-24 (J. J. D.); Greene Co., emerged July 30 (J.J.D.); Posey Co., emerged Oct. 25 (J.J.D.); Shelby Co., emerged Aug. 25 (J.J.D.); Tippecanoe Co., Sept. 2-Oct. 21 (J.J.D.).

A. c-nigrum L. (1424). Spotted cutworm. Numerous from May to October. DeKalb Co., May 18-Oct. 19; Greene Co., emerged May 20 (J.J.D.); Huntington Co., emerged May 28 (J.J.D.); Starke Co., emerged Aug. 15-Sept. 11 (J.J.D.); Steuben Co., June 11, 12, 16, 24 (G.R.); Tippecanoe Co., emerged July 12-Sept. 7 (J.J.D.); Warren Co., emerged July 19 (J.J.D.).

A. bicarnea Gn. (1425). A common cutworm. DeKalb Co., Aug. 15-Sept. 14; Tippecanoe Co., May 16, July 28 (J.J.D.).

A. baja Fabr. (1430). DeKalb Co., July 1.

A. plecta L. (1434). A common cutworm. DeKalb Co., May 29-July 29; Steuben Co., June 4, 16 (G.R.); Tippecanoe Co., July 25 (J.J.D.).

A. phyllophora Grt. (1444). Unmarked cutworm. DeKalb Co., July 6.

A. unicolor Wlk. (1461). W-marked cutworm. Common in sandy and gravelly soils in northern Indiana. DeKalb Co., June 1-July 30; Elkhart Co., June 2-Aug. 4; Fulton Co., June 8 (J.J.D.); Steuben Co., Sept. 6 (G.R.).

A. lubricans Gn. (1502). DeKalb Co., June 2-July 25.

Genus EPIPSILIA Hbn.

E. fungorum G. & R. (1471). A cutworm. DeKalb Co., Sept. 21.

Genus LYCOPHOTIA Hbn.

L. occulta L. (1489). A cutworm. DeKalb Co., Aug. 21.

L. margaritosa Haw. (1490). Variegated cutworm. Common from June to October. One of the most numerous and destructive cutworms.

Var. *saucia* Hbn. Occurs at the same time as the typical form.

Var. *semifusca* Butl. is found commonly together with the normal species and the var. *saucia* Hbn. The species breeds throughout the winter in greenhouses where the var. *semifusca* Butl. is frequently the most numerous. DeKalb Co., June 3-Oct. 17; Starke Co., emerged Sept. 12, 18 (J.J.D.); Steuben Co., June 23, Aug. 17, 19 (G.R.); Tippecanoe Co., emerged July 6-Oct. 14 (J.J.D.).

L. infecta Ochs. (1495). Green cutworm. DeKalb Co., Aug. 2.

L. lubricans Gn. (1502). DeKalb Co., Aug. 10.

Genus RYNCHAGROTIS Sm.

R. rufipectus Morr. (1565). Common. DeKalb Co., June 16-Aug. 16.

R. alternata Grt. (1588). Mottled-gray cutworm. Common. DeKalb Co., June 14-Sept. 4; Tippecanoe Co., emerged June 11-July 8 (J.J.D.).

R. anchocelioides Gn. (1589). Reared from larvae taken in sandy and gravelly soils. Elkhart Co., emerged June 17, 20; Steuben Co., May 19 (G.R.).

R. cupida Grt. (1590). Brown cutworm. A common and destructive climbing cutworm in orchards. Confined largely to sandy and gravelly soils. Elkhart Co., emerged June 14-July 18; Tippecanoe Co., July 3 (J.J.D.).

R. barnesi French. (...). Barnes' climbing cutworm. The most common and destructive climbing cutworm affecting orchards. Confined largely to light soils. Elkhart Co., emerged June 14-July 26.

Genus SCOTOGRAMMA Sm.

S. trifolii Rott. (1615). Clover cutworm. Common throughout Indiana. DeKalb Co., June 2-Sept. 14; Steuben Co., July 5-Aug. 30 (G.R.); Tippecanoe Co., Aug. 3 (J.J.D.).

Genus POLIA Ochs.

P. imbrifera Gn. (1661). DeKalb Co., July 14.

P. meditata Grt. (1673). Pink-backed cutworm. Common. DeKalb Co., July 5-Sept. 13.

P. grandis Bdv. (1685). A cutworm. DeKalb Co., June 17, 21.

P. subjuncta G. & R. (1686). Speckled cutworm. A common species occurring throughout the area from May to September. DeKalb Co., May 28-Sept. 13; Steuben Co., June 11-Aug. 17 (G.R.); Tippecanoe Co., Aug. 5 (J.J.D.).

P. cristifera Wlk. (1693). Not common. But one specimen has been taken. DeKalb Co., June 2.

P. latex Gn. (1695). A cutworm. One specimen has been taken. DeKalb Co., June 7.

P. adjuncta Bdv. (1700). Allen Co., May 28.

P. legitima Grt. (1715). Striped garden caterpillar. Common and destructive. DeKalb Co., June 10-Sept. 12.

P. renigera Steph. (1750). Bristly cutworm. The commonest cutworm of this genus, occurring in two broods from May to October. DeKalb Co., May 27-Oct. 16; Greene Co., emerged June 7, 10 (J.J.D.); Orange Co., emerged Sept. 12 (J.J.D.); Starke Co., emerged Sept. 5, 6 (J.J.D.); Tippecanoe Co., July 12-Oct. 1 (J.J.D.); Wayne Co., emerged Sept. 7, 12 (J.J.D.).

P. lorea Gn. (1754). A general and common cutworm but not a serious pest. DeKalb Co., June 4-17.

Genus CHABUATA Wlk.

C. signata Wlk. (1798). DeKalb Co., Aug. 8; Tippecanoe Co., emerged Aug. 22 (J.J.D.).

Genus ERIOPYGA Gn.

E. crenulata Butl. (1838). A cutworm. Common. DeKalb Co., June 6-Sept. 2.

E. synica Gn. (1839). A cutworm. July 7, 8.

E. vecors Gn. (1842). A cutworm. DeKalb Co., May 28.

Genus NEPHELODES Gn.

N. emmedonia Cram. (1866). Bronze cutworm. A common cutworm. DeKalb Co., Sept. 4-Oct. 19; Tippecanoe Co., Sept. 4, 9, 12, 14 (J.J.D.).

Genus MORRISONIA Grt.

M. confusa Hbn. (1878). Posey Co., May 14 (J.J.D.).

Genus ORTHOSIA Ochs.

O. germani Grt. (1915). Greene Co., April 11 (J.J.D.).

O. hibisci Gn. (1919).

Var. *alia* Auct. A "green fruitworm" on apple. The following records are of this variety: Tippecanoe Co., Nov. 25, May 9 (P.L.).

Genus CERAMICA Gn.

C. picta Harr. (1930). Zebra caterpillar. Common. DeKalb Co., May 14-July 10; Greene Co., May 16 (A.F.S.); Tippecanoe Co., May 20 (P.S.C.).

Genus CIRPHIS Wlk.

C. pseudargyria Gn. (1933). DeKalb Co., June 16; Steuben Co., June 2, July 12 (G.R.); Tippecanoe Co., May 3, emerged Aug. 9, Sept. 13 (J.J.D.).

C. commoides Gn. (1935). Apparently rare. DeKalb Co., June 28.

C. phragmatidicola Gn. (1936). Yellow armyworm. An armyworm common from May to October. DeKalb Co., May 23-Oct. 6; Steuben Co., June 11, 15, 19 (G.R.); Tippecanoe Co., Aug. 2, 18 (J.J.D.).

C. unipuncta Haw. (1950). Common armyworm. Abundant throughout the season from early May to October and frequently widely destructive. Clinton Co., July 16, 17 (C.R.C.); DeKalb Co., May 12-Oct. 19; Fulton Co., emerged July 31 (J.J.D.); Starke Co., July 10 (C.R.C.); Steuben Co., June 6, 26, July 4 (G.R.); Tippecanoe Co., May 7-Oct. 28 (J.J.D.).

C. inermis Fbs. (. . . .). DeKalb Co., June 11.

C. ursula Fbs. (. . . .). Common. DeKalb Co., June 28-Aug. 8.

Genus NELEUCANIA Sm.

N. albilinea Hbn. (1959).

Var. *diffusa* Wlk. Wheat-head armyworm. Both forms present and common. Clark Co., April 15-Aug. 23 (P.S.C.); DeKalb Co., June 17-Aug. 11; Fulton Co., emerged Aug. 23 (J.J.D.); Kosciusko Co., emerged Aug. 27 (J.J.D.); Tippecanoe Co., May 13, 28 (P.S.C.).

Genus CUCULLIA Schrank

C. asteroides Gn. (2003). Clark Co., April 12-Aug. 23 (P.S.C.); DeKalb Co., June 22-Aug. 4; Sullivan Co., Aug. 12 (J.J.D.); Tippecanoe Co., May 11, 13, 15, 16, 20, 21, 28 (P.S.C.).

Genus EUTOLYPE Grt.

E. depilis Grt. (2109). DeKalb Co., April 4.

Genus GRAPTOLITHA Hbn.

G. bethunei G. & R. (2131). DeKalb Co., April 27; Tippecanoe Co., Sept. 25 (J.J.D.).

G. innominata Sm. (2133). Tippecanoe Co., March 25 (P.L.).

G. ferrealis Grt. (2137). Tippecanoe Co., Sept. 26 (J.J.D.).

G. signosa Wlk. (2139). Tippecanoe Co., emerged Sept. 2 (J.J.D.).

G. unimoda Lint. (2150). DeKalb Co., Oct. 21; Tippecanoe Co., March 25 (P.L.).

Genus PARASTICHTIS Hbn.

P. bicolorago Gn. (2220).

Var. *ferrugineoides* Gn. Shield-marked cutworm. These moths appear in numbers in late fall. DeKalb Co., Sept. 14-Oct. 19; Greene Co., July 31 (A.F.S.).

Genus ATETHMIA Hbn.

A. pampina Gn. (2230). DeKalb Co., Aug. 8.

Genus AMPHIPYRA Ochs.

A. pyramidoides Gn. (2239). Common in bait traps. Clark Co., June 20-July 28 (P.S.C.); DeKalb Co., July 27-Sept. 26.

A. tragopoginis L. (2240). DeKalb Co., Aug. 8, Sept. 9.

Genus DIPTERYGIA Steph.

D. scabriuscula L. (2243). Numerous during the summer months. DeKalb Co., June 2-Sept. 17; Tippecanoe Co., July 31 (F.A.F.); Aug. 13, 27, Sept. 15 (J.J.D.).

Genus SEPTIS Hbn.

S. verbascoides Gn. (2246). DeKalb Co., June 2, 8; Elkhart Co., June 21.

S. cariosa Gn. (2248). DeKalb Co., July 31.

S. lignicolor Gn. (2253). Common and numerous. DeKalb Co., June 6-July 14.

S. plutonia Grt. (2264). DeKalb Co., June 16-July 14.

S. arctica Bdv. (2268). Yellow-headed cutworm. A common and destructive species. DeKalb Co., June 9-Aug. 9; Steuben Co., July 12, 23 (G.R.).

Genus TRACHEA Ochs.

T. delicta Grt. (2271). Numerous. DeKalb Co., June 1-Aug. 17; Tippecanoe Co., emerged May 29 (J.J.D.).

Genus PERIGEA Gn.

P. xanthoides Gn. (2323). DeKalb Co., June 20.

P. vecors Gn. (2327). DeKalb Co., July 11, Sept. 13.

Genus OLIGIA Hbn.

O. fractilinea Grt. (2335). DeKalb Co., July 16.

Var. *modiola* Grt. is more common. DeKalb Co., July 16, 17, Aug. 18, 20.

O. diversicolor Morr. (2339). Delaware Co., Aug. 21 (A.F.S.).

Genus AGROPERINA Hamp.

A. dubitans Wlk. (2344). A common cutworm. DeKalb Co., June 2-Sept. 14.

A. helva Grt. (2357). DeKalb Co., Aug. 1-15.

Genus MACRONOCTUA Grt.

M. onusta Grt. (2365). Iris borer. DeKalb Co., June 30.

Genus SIDEMIA Staud.

S. devastator Brace. (2367). Glassy cutworm. Common and destructive. DeKalb Co., June 17-Sept. 23; Tippecanoe Co., Aug. 5 (J.J.D.).

Genus LUPERINA Bdv.

L. passer Gn. (2380). DeKalb Co., Aug. 13.

Genus PHLOGOPHORA Tr.

P. iris Gn. (2384). DeKalb Co., June 13.

Genus LEUCONYCTA Hamp.

L. diphteroides Gn. (2418). DeKalb Co., May 18.

Var. *obliterata* Grt. is more common. DeKalb Co., May 18-Aug. 26.

Genus ACRONYCTA Ochs.

A. connecta Grt. (2433). DeKalb Co., July 28.

A. pruni Harr. (2438). DeKalb Co., June 20-July 1.

Var. *prunata* S. & B. appears to be scarce. DeKalb Co., May 28.

A. inclara Sm. (2444). DeKalb Co., Aug. 8.

A. afflicta Grt. (2450). DeKalb Co., Aug. 10, 22, July 7; St. Joseph Co., July 10 (A.W.T.).

A. hasta Gn. (2461). The dark form only has been taken. DeKalb Co., July 28.

A. elizabeta Sm. (2466). DeKalb Co., July 28, Aug. 8.

A. morula G. & R. (2473). Only the dark form has been taken. DeKalb Co., July 11, 28.

A. interrupta Gn. (2474). DeKalb Co., June 28, July 27, 28.

A. populi Riley. (2488). DeKalb Co., Aug. 12.

A. americana Harris. (2491). DeKalb Co., June 23; Steuben Co., July 12 (G.R.).

A. oblinita A. & S. (2508). DeKalb Co., June 22, July 2, Aug. 8, 16.

A. insolita Grt. (2510). DeKalb Co., Aug. 12.

Genus SIMYRA Ochs.

S. henrici Grt. (2514). DeKalb Co., June 22, 24, July 22.

Genus DELTA Saalm.

D. ramosula Gn. (2515). DeKalb Co., May 20, Oct. 12; Posey Co., Nov. 8 (S.L.M.).

Genus HYPPA Dup.

H. xylinoides Gn. (2531). Very numerous. DeKalb Co., May 18-Sept. 4.

Genus PRODENIA Gn.

P. ornithogalli Gn. (2569). Yellow-striped armyworm, cotton cutworm. Common throughout the state, frequently occurring in outbreak numbers. DeKalb Co., June 18-Oct. 19; Tippecanoe Co., Aug. 31 (A.F.S.), April 19-Nov. 2 (J.J.D.).

Genus LAPHYGMA Gn.

L. frugiperda A. & S. (2574). Fall armyworm. Probably a migrant to northern Indiana, occurring in limited numbers in September and October. DeKalb Co., Sept. 30, Oct. 6; Tippecanoe Co., Sept. 12 (J.J.D.); Dearborn Co., Nov. 10, 13 (C.R.C.).

Genus CARADRINA Ochs.

C. tarda Gn. (2581). DeKalb Co., Aug. 12.

Genus PROXEMUS H. S.

P. miranda Grt. (2990). DeKalb Co., June 11; Tippecanoe Co., emerged April 19 (J.J.D.).

Genus PLATYSENTA Grt.

P. videns Gn. (2598). DeKalb Co., May 3, June 11.

Genus Balsa Wlk.

B. malana Fitch. (2600). DeKalb Co., May 27, June 1, 17.

Genus HELIOTROPHA Led.

H. reniformis Grt. (2636). DeKalb Co., Oct. 1.

Var. *arta* Grt. DeKalb Co., July 25, 30, Oct. 3.

Genus APAMEA Ochs.

A. velata Wlk. (2637). DeKalb Co., June 18, 23, July 13.

Genus ACHATODES Gn.

A. zaeae Harris. (2642). DeKalb Co., Aug. 5.

Genus PAPAPEMA Sm.

P. inquaesita G. & R. (2661). DeKalb Co., Sept. 28.

P. marginidens Gn. (2663). Allen Co., Aug. 24, 28; DeKalb Co., Aug. 17.

P. furcata Sm. (2667). DeKalb Co., Aug. 1, 4.

P. cataphracta Grt. (2686). DeKalb Co., Sept. 23, 28.

- P. cerussata* Grt. (2696). DeKalb Co., Sept. 6.
P. nebris Gn. (2698). Common stalk borer. Allen Co., Aug. 24, 29.
Var. *nitela* Gn. DeKalb Co., Sept. 9, 23, 25; Tippecanoe Co., Aug. 12 (J.J.D.).

Genus IPIMORPHA Hbn.

- I. pleonectusa* Grt. (2724). DeKalb Co., July 27.

Genus ARZAMA Wlk.

- A. obliqua* Wlk. (2784). Fulton Co., May 23 (J.J.D.); Tippecanoe Co., emerged May 8, 11 (J.J.D.).

Genus ARCHANARA Hbn.

- A. sublava* Grt. (2792). DeKalb Co., Aug. 11.

Genus EUTHASONOTIA Hbn.

- E. grata* Fabr. (2827). Porter Co., June 27 (A.W.T.); Allen Co., June 23, 28; DeKalb Co., May 5.

Genus CHAMYRIS Gn.

- C. cerintha* Treit. (2891). DeKalb Co., June 11, July 15; Tippecanoe Co., June 14 (G.E.G.).

Genus LETHACODIA Hbn.

- L. carneola* Gn. (2900). DeKalb Co., May 25, 26; Tippecanoe Co., June 13 (G.E.G.).

Genus CATOCALA Schrank.

- C. innumbens* Gn. (3020). DeKalb Co., June 28, July 17, Aug. 6, 13.
C. epione Drury. (3023). DeKalb Co., July 23, Aug. 16.
C. obscura Stkr. (3025). DeKalb Co., July 29.
C. palaeogramma Gn. (3045). DeKalb Co., Aug. 6, 10.
C. ilia Cram. (3051). DeKalb Co., July 8, 29, Aug. 8.
C. marmorata Edw. (3045). DeKalb Co., Aug. 11, 13.
C. unijuga Wlk. (3068). DeKalb Co., July 8.
C. cara Gn. (3081). DeKalb Co., July 26, 28, Aug. 13, 22.
C. concumbens Wlk. (3082). DeKalb Co., Aug. 5, 6, 11.
C. amatrix Hbn. (3083). DeKalb Co., Aug. 10, 13, 28.
C. illecta Wlk. (3088). DeKalb Co., July 10, 28, Aug. 6, 8.
C. ultronia Hbn. (3103). DeKalb Co., July 23, Aug. 10.
C. grynea Cram. (3106). DeKalb Co., July 22, Aug. 10.

Genus PARALLELIA Hbn.

- P. bistriaris* Hbn. (3127). DeKalb Co., June 11, July 16.

Genus CAENURGIA Wlk.

- C. erectea* Cram. (3135). An alfalfa looper. Common. DeKalb Co., May 22-Aug. 29; Tippecanoe Co., April 26 (G.E.G.).
C. crassiuscula Harr. (3136). DeKalb Co., May 12.

Genus ARGYROSTROTIS Hbn.

A. anilis Dru. (3164). DeKalb Co., June 17, 19, July 6, Aug. 10; Tippecanoe Co., Sept. 5 (J.J.D.).

Genus ZALE Hbn.

Z. lunata Dru. (3175). Common. DeKalb Co., June 10-Aug. 21; Steuben Co., June 14 (J.J.D.).

Genus AUTOGRAPHHA Hbn.

A. falcifera Kirby. (3230). Celery looper. Tippecanoe Co., June 1 (G.E.G.); DeKalb Co., May 2, 4, June 30, July 26.

A. brassicae Riley. (3249). Cabbage looper. Very common and sometimes destructive. DeKalb Co., July 9, Aug. 5; Tippecanoe Co., Aug. 19 (G.E.G.); Steuben Co., Aug. 6 (G.R.).

A. basigera Wlk. (3251). DeKalb Co., June 25, 26.

A. biloba Steph. (3259). DeKalb Co., May 3, 6, June 28, July 26.

A. oo Cram. (3260). DeKalb Co., May 8.

Var. rogationis Gn. Starke Co., Sept. 14 (J.J.D.); Starke Co., Aug. 21 (J.J.D.).

A. pseudogenma Grt. (3266). DeKalb Co., June 18.

Genus PLUSIA Ochs.

P. aerea Hbn. (3276). DeKalb Co., June 2, 19, 28.

P. balluca Geyer. (3277). DeKalb Co., June 26.

Genus ABROSTOLA Ochs.

A. urentis Gn. (3286). DeKalb Co., June 28.

Genus MELIPOTIS Hbn.

M. jucunda Hbn. (3312). DeKalb Co., July 22, Aug. 26.

Genus TOXOCAMPA Gn.

T. victoria Grt. (3338). DeKalb Co., June 2, July 22, 23.

Genus STRENOLOMA Grt.

S. lunilinea Grt. (3365). DeKalb Co., June 17, 28.

Genus SCOLIOPTERIX Germ.

S. libatrix L. (3399). DeKalb Co., July 14, June 23; Steuben Co., June 3, July 3, 11 (G.R.).

Genus PLUSIODONTA Gn.

P. compressipalpis Gn. (3400). DeKalb Co., June 15, July 16; Lawrence Co., May 3 (G.E.M.); Porter Co., July 28 (A.W.T.).

Genus ALABAMA Grt.

A. argillacea Hbn. (3406). Cotton worm. Occurs during late summer and fall, a probable migrant from the South. DeKalb Co., Sept. 28, 30; Greene Co., Sept. 26 (J.J.D.); Greene Co., emerged June 23 (J.J.D.).

Genus EPIZEUXIS Hbn.

E. lubricalis Geyer. (3496). Elkhart Co., June 11.

Genus HORMISA Wlk.

H. bivittata Grt. (3514). DeKalb Co., July 13.

H. orciferalis Wlk. (3515). Greene Co., emerged June 23 (J.J.D.).

Genus BOMOLOCHA Hbn.

B. bijugalis Wlk. (3562). DeKalb Co., May 20, 28, 30, June 20.

Genus PLATHYPENA Grt.

P. scabra Fabr. (3578). DeKalb Co., July 6.

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